3/23-3 days —

U. S. Geol. Survey,
Jan. 30, 1886.

ADVERTISEMENT.

["Mineral Resources of the United States, 1883 and 1884."]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the Library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this Office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth and Sixth Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz.:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

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The following are in press, viz.:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl.

The following are in preparation, viz.:

I. The Precious Metals, by Clarence King.

— Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

— Lake Bonneville, by G. K. Gilbert.

— Sauropoda, by Prof. O. C. Marsh.

— Stegosauria, by Prof. O. C. Marsh.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient sizes. To facilitate this, each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 21 are already published, viz.:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 10 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; and Numbers 15 to 23, Volume III. Volume IV is not yet complete.

ADVERTISEMENT.

The following are in press, viz.:

22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. The Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, by R. D. Irving and T. C. Chamberlin. 1885. 8°. — pp. 17 pl. Price — cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by W. H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 82 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. — pp. Price — cents.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, is contemplated.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER (not stamps), should be addressed

To the Director of the
United States Geological Survey,
Washington, D. C.

Washington, D. C., *September* 1, 1885.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL DIRECTOR

MINERAL RESOURCES

OF THE

UNITED STATES

CALENDAR YEARS
1883 and 1884

ALBERT WILLIAMS Jr.
CHIEF OF DIVISION OF MINING STATISTICS AND TECHNOLOGY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1885

The U. S. Geol. Survey,
Jan. 30, 1886

NOTICE.

This volume, "Mineral Resources of the United States, 1883 and 1884," is the second of the series. Its price is 60 cents. The price of the first volume, "Mineral Resources of the United States," is 50 cents. Remittances should be made by postal note (not stamps), and should be addressed to the Director, United States Geological Survey, Washington, D. C. In ordering the volumes of this series care should be taken to designate the first as "Mineral Resources, 1882," the second as "Mineral Resources, 1883 and 1884."

Corrections, additions, or notice of important omissions, reports and maps of mines or mining districts, pamphlets on metallurgical processes, brief notes on new mineral localities, etc., will be highly appreciated, and should be addressed to Albert Williams, jr., U. S. Geological Survey, Washington, D. C. Duplicate copies of all such reports, maps, pamphlets, or notes as are actually published are especially desired for continuing the already fine set of mining pamphlets, etc., in the library of the Survey, and will be thankfully acknowledged if sent

To the Director of the
United States Geological Survey,
Washington, D. C.

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LETTER OF TRANSMITTAL.

UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF MINING STATISTICS AND TECHNOLOGY,
Washington, D. C., June 9, 1885.

SIR: I have the honor to transmit herewith a statistical report upon the present condition of the mining industries of the United States. This report is the second of the series, the first volume having been issued in 1883. The earlier report brought the statistics of production to the close of 1882, with estimates for the first half of 1883. The present report carries the statistics to December 31, 1884, and is entitled "Mineral Resources of the United States, Calendar Years 1883 and 1884." In accordance with your instructions, it is proposed to issue a third volume (for the calendar year 1885) early in 1886.

Very respectfully, your obedient servant,

ALBERT WILLIAMS, JR.,
Geologist in charge.

HON. J. W. POWELL,
Director United States Geological Survey.

INTRODUCTORY.

Acknowledgments.—Contributed papers appear under the names of the writers; but it has been found impossible to give credit for much of the information received from agents and correspondents. As was said in a former report, a mere mention of the names of those who have responded, often at considerable sacrifice of time and trouble, to the thousands of inquiries which have been addressed to them through the mails, would in itself occupy many pages. It would be ungracious, however, to omit testifying to the uniform courtesy and interest displayed by miners, manufacturers, and dealers in mineral products, without whose public spirit and cordial co-operation little could be accomplished.

Scope of the report.—This volume is for the calendar years 1883 and 1884. While it bears the same title, with the exception of the date, as the former one ("Mineral Resources of the United States," published in 1883), it is not a reprint or second edition of that report. The tables of production are reproduced; but it has been the endeavor to avoid so far as possible, repetition of the descriptive matter—a difficult question sometimes, as for certain mineral industries there is little to add to what has already been said, and as the text of the first report was too concise to bear further condensation. The two volumes should be consulted together. Some of the minor topics treated of in the first report, but regarding which no changes have occurred in the last two years, are omitted. On the other hand, some subjects which were not adequately discussed before are now dealt with at considerable length. This causes an apparent want of proportion between the space allotted to some of the subjects and their relative importance. Such disproportion has seemed unavoidable.

The gold and silver mining industries have been reported on by the late Director of the Mint for the years 1880, 1881, 1882, and 1883; and his report for 1884 will be issued during the present year. It is deemed unadvisable to duplicate this work, and the matter here given is merely a compact statement of the production statistics, in which the estimates of the Director of the Mint for the last four years are accepted as official.

Close of the time covered by this report.—In justification of the statements made by specialists who have contributed to this volume it should be stated that their reports and those of agents represent their views at the time of writing, which in most instances was immediately after the close of the year 1884. The unavoidable delay in publication of this volume has allowed the lapse of time which has developed some new features, but as this is professedly a report covering only the time ending December 31, 1884, it has been deemed unadvisable to add statements of later events, which will be more properly discussed in a subsequent volume, though in a very few cases late notes have been inserted.

Delay in publication.—Although strenuous efforts were made to complete this work at an earlier date, it was found impracticable to do so. The value of statistical publications depends very largely upon the promptness with which they are issued, and the gentlemen who have assisted in the collection of these statistics were fully impressed with the importance of this consideration. In a compilation covering so many details of equal weight delay in a few branches, or even in a single one, suffices to retard the completion of the whole, no matter how forward the condition of the mass of the matter may be.

Arrangement of matter.—The form of presentation adopted is that which leads to convenience of reference. The sections are divided according to the mineral products discussed, the geographical distribution of occurrences being subsidiary to the grouping by substances. In this way everything relating to copper, for example, will be found in one portion of the book; everything relating to salt, in another, with some few exceptions, where the overlapping is indicated by cross-references. Thus a glance at the table of contents will show where to look for information of a given kind.

Character of the production statistics.—In the case of some products, as for example, quicksilver, the statistics are accurate to the last unit; in others, as iron, they are probably correct to within a small fraction of 1 per cent.; in others, as copper, lead, zinc, mineral waters, salt, etc., they rest upon a large mass of exact individual returns, in which, however, gaps have to be filled by estimates; in still others, as pyrites, natural gas, etc., the totals represent a consolidation of estimates for the several producing localities; in others, as lime, cement, building stone, etc., the figures are the lump estimates of authorities, based on the known changes in the state of the industries since the collection of the census statistics; and finally, some of the estimates are simply the best guesses possible under the circumstances. It has been the endeavor to show with perfect frankness the relative reliability or credibility of these different grades of figures; and indeed, when a product is stated at "about 30,000 tons, worth about $120,000," the use of the round figures speaks for itself. But it will be generally admitted that a round estimate, put forth for what it is honestly worth and no more, is not only better than nothing, but often better than incomplete returns obtained by direct canvass, so far as the total is concerned. And to conduct a complete direct canvass—that is, a census—of all the mineral industries would be out of the question, the expense of the tenth census in the same field having been not less than forty, and probably more than fifty, times more than the entire cost of the present volume or its predecessor.

The unit of quantity adopted is that commonly used in the several trades. It is a misfortune that the standards of weights and measures accepted in this country are not more uniform; but it is questionable whether a reduction of the units of quantity to uniform terms would much help the matter, since the usage is so different in different industries and also in different parts of the United States.

The ton of 2,240 pounds is in this report called the "long" ton, and that of 2,000 pounds is called the "short" ton; the terms "gross" ton and "net" ton being sometimes misleading, as for instance where "gross ton of ore" might be taken to mean a ton (of perhaps only 2,000 pounds) including moisture, or where "net" might be understood as referring to the weight after deducting the tare of package, etc. In quoting statistics of the European continent the "metric" ton (tonne) of 2,204 pounds avoirdupois is generally adopted and is specified. For Great Britain and its colonies the long ton of 2,240 pounds is the unit. Pounds are avoirdupois throughout, unless otherwise specified.

The statistics of the weights of imports into and exports from the United States are quoted in long tons and long hundredweights (112 pounds), these being the units adopted at the custom-houses.

Calendar and fiscal years.—Unless otherwise specified, years are understood to be calendar years ending December 31. The Government fiscal year ends June 30, and is designated by the number of the calendar year in which it is completed. Imports and exports, with a very few exceptions, are given by fiscal years because they are thus reported by the Treasury Department, and because a considerable delay would ensue if a computation by calendar years were attempted. It is admitted that for purposes of comparison the calendar year would be a more convenient time unit.

Imports and exports.—The very valuable statistics of imports and exports, obtained through the courtesy of the Bureau of Statistics of the Treasury Department, need a word of explanation, inasmuch as some of the tables of back statistics of imports given in this report differ considerably from those published in the former volume of this series. This apparent discrepancy does not involve an error, however. Both sets of figures are correct. The Bureau of Statistics of the Treasury Department, in its annual reports on "commerce and navigation," has, since 1867, published two kinds of import tables: The first embraces (1) imported articles entered for immediate consumption on arrival, plus (2) entries of imported articles for warehouse; the second form of table shows the imports entered for consumption, with rates of duty and amounts of duty collected on each article, and embraces (1) articles entered for immediate consumption on arrival, plus (2) articles withdrawn from warehouse for consumption. The latter import table affords a better idea than the first of the consumption of the various imported articles, but the total value of the articles which would appear in one table would in many cases differ from the amount shown in the other table by the difference between the amount entered for warehouse and the amount withdrawn from warehouse for consumption. The present import figures are therefore based upon quarterly returns, which include (1) "entries for immediate consumption," plus (2) "withdrawals from warehouse for consumption." These give a clearer view of the consumption in this country than figures including in part entries for warehouse, since the classification and appraisal are more accurate when goods are taken out of warehouse than when first sent to warehouse on a provisional classification. For example, imported iron pyrites containing some copper might at first be classed, on entry, as sulphur ore or iron ore; and afterwards, on appraisal at the time of withdrawal, be known as copper ore, according to the application of the tariff rules. The withdrawals from warehouse are also evidently a better guide as to the demand for consumption during a given period than are the entries for warehouse.

MINERAL RESOURCES OF THE UNITED STATES.

CALENDAR YEARS 1883 AND 1884.

ALBERT WILLIAMS, JR.,
Chief of Division of Mining Statistics and Technology.

SUMMARY—1884.

Coal.—The only statistics in which the trade is interested are those relating to the amount of coal which is mined for and reaches the market. There is besides a local and colliery consumption which is usually disregarded in statistics, and which ranges from 5 to 6½ per cent. of the total shipments. Of what may be called the commercial product the quantities in 1884 were as follows: Pennsylvania anthracite, 30,718,293 long tons; bituminous and brown coal, lignite, and small lots of anthracite mined elsewhere than in Pennsylvania, 66,809,356 long tons; total, 97,527,649 long tons. The spot value of the commercial product was: Pennsylvania anthracite, $61,436,586; bituminous and all other coals, $70,149,824; total, $131,586,410. Including the local consumption, etc., the total product in 1884 may be stated at 106,906,295 long tons; namely, 33,175,756 long tons of Pennsylvania anthracite and 73,730,539 long tons of bituminous and all other coals; and the value at the mines was: Pennsylvania anthracite, $66,351,512; bituminous and all other coals, $77,417,066; total, $143,768,578. The total production (that is, including colliery and local consumption) of anthracite was 1,160,713 long tons less than in 1883, while its value was $10,905,543 less, the disproportionate decline in value being due to a fall of 25 cents per ton in spot price ($2.25 to $2). The total bituminous coal production increased 5,199,039 long tons over that of 1883; but its value was $4,820,734 less, the average valuation at the collieries having fallen from $1.20 to $1.05. The total output of all coals showed a net gain in tonnage of 4,038,326 long tons and a decline in value of $15,726,277.

Coke.—There were 4,873,805 short tons of coke made in 1884, worth $7,242,878 at the ovens. This production consumed 7,951,974 short tons of coal. The amount of coke made was 590,916 tons less than in 1883, and the value was $878,729 less.

Petroleum.—The production of crude petroleum in 1884 was 24,089,758 barrels of 42 gallons each, of which the Pennsylvania and New York oil fields produced 23,622,758 barrels. The total value, at an average spot price of 85 cents, was $20,476,294. As compared with 1883 the production was 689,529 barrels greater; but the total value was $5,263,958 less, the average spot price having fallen from $1.10, or 25 cents per barrel.

Natural gas.—The estimated value of the natural gas used in the United States in 1884 was $1,460,000, as against $475,000 in 1883. The value is computed from that of the coal superseded by natural gas.

Iron.—The principal statistics for 1884 are as follows: Iron ore mined, 8,200,000 long tons; value at mine, $22,550,000. Domestic iron ore consumed, 7,718,129 long tons; value at mine, $21,224,854. Imported iron ore consumed, 487,820 long tons; total iron ore consumed, 8,205,949 long tons. Pig iron made, 4,097,868 long tons, a decrease of 497,642 tons as compared with 1883; value at furnace, $73,761,624, or $18,148,576 less than in 1883. Total spot value of all iron and steel in the first stage of manufacture, excluding all duplications, $107,000,000, a decline of $35,000,000 from 1883. Fuel consumed in all iron and steel works, including blast furnaces, 1,973,305 long tons of anthracite, 4,226,986 long tons of bituminous coal, 3,833,170 long tons of coke, and 62,110,660 bushels of charcoal, besides a notable quantity of natural gas. Limestone used as flux, 3,401,930 long tons; value at quarry, $1,700,965.

Gold and silver.—The mint authorities estimate the production in 1884 at $30,800,000 gold and $48,800,000 silver (coining rate); total, $79,600,000. This was an increase of $800,000 gold and $2,600,000 silver, as compared with 1883. The gold production was equivalent to 1,489,949 troy ounces; and the silver to 37,744,605 troy ounces.

Copper.—The production in 1884, including 2,858,754 pounds made from imported pyrites, was 145,221,934 pounds, worth $17,789,687, at an average price of 12¼ cents per pound in New York City. The amount was 28,070,139 pounds greater than the production of 1883; but the value was $275,120 less than that for 1883, owing to the decline in price. In 1884 4,224,000 pounds of bluestone (sulphate of copper, "blue vitriol") were made; worth, at 4.3 cents per pound, $181,632.

Lead.—Production, 139,897 short tons. Total value, at an average price of $75.32 per ton on the Atlantic sea-board, $10,537,042. The production was 4,060 tons less than that of 1883, while the decrease in value was $1,785 677. The production of white lead (carbonate) is estimated at about 65,000 short tons, worth, at 4⅞ cents per pound, $6,337.500, almost all of which was made from pig lead. The production of litharge and red lead has not been ascertained.

Zinc.—Production of metallic zinc, 38,544 short tons; worth, at an average price of 4.44 cents per pound in New York City, $3,422,707.

The output was 1,672 tons greater than in 1883, and the value increased $111,601. Besides the spelter and sheet zinc, about 13,000 short tons of zinc white (oxide) were made directly from the ore, the total value of which, at 3½ cents per pound, was $910,000.

Quicksilver.—Production, 31,913 flasks (of 76½ pounds net = 2,441,344 pounds), or 14,812 flasks less than in 1883. Total value, at an average price of $29.34 per flask at San Francisco, $936,327, a decline of $317,305 as compared with the total value of the product of the previous year. During the year 600,000 pounds of quicksilver vermilion were made, worth $288,000.

Nickel.—Production of nickel contained in copper-nickel alloy, 64,550 pounds, worth, at 75 cents per pound, $48,412; an increase of 5,750 pounds, but a decline of $4,508 in total value, owing to the falling off in price.

Cobalt.—The amount of cobalt oxide made in 1884 was about 2,000 pounds, as against 1,096 pounds made in 1883. Its value, at $2.55 per pound, was $5,100. The value of cobalt ore and matte cannot be ascertained, as it is chiefly dependent on the nickel contents.

Manganese.—The output of manganese ore in 1884 was about 10,000 long tons, or 2,000 tons more than in 1883. The total value, at $12 per ton at the mines, was $120,000, or about the same as in 1883, the average price having declined $3 per ton.

Chromium.—The production of chrome iron ore, all from California, was about 2,000 long tons, or about two-thirds as much as in 1883. At an average value of $17.50 per ton at San Francisco, the total value was $35,000.

Tin.—A little tin ore was taken out in the course of development work in Dakota, Wyoming, Virginia, and Alabama, but the only metallic tin made was a few hundred pounds from ore of the Black Hills (Dakota) mines made in sample tests at New York City pending the building of reduction works at the mines.

Platinum.—The amount mined in 1884 was about 150 troy ounces, worth, crude, $3 per ounce.

Aluminum.—The amount made in the United States in 1884 was 1,800 troy ounces, an increase of 800 ounces over the production in 1883. At 75 cents per ounce the total value was $1,350.

Building stone.—It is estimated that the value of the building stone quarried in 1884 was $19,000,000, as against $20,000,000 in 1883; the decline being due partly to dullness of trade and partly to the increased use of other structural materials.

Brick and tile.—The output was about the same as in 1883, but as manufacturers cut down expenses still further, meeting a lower market, the total value is estimated at $30,000,000 as against $34,000,000 in 1883.

Lime.—There were 37,000,000 barrels (of 200 pounds) made in 1884, the average value per barrel at the kilns being not over 50 cents, or

$18,500,000. The production was about 5,000,000 barrels greater than in 1883, but owing to the fall in price the total value was about $700,000 less.

Cement.—About 100,000 barrels (of 400 pounds) of artificial Portland cement were made, or 10,000 barrels more than in 1883; the total value, at $2.10 per barrel, being $210,000. The production of cement from natural cement rock was 3,900,000 barrels (of 300 pounds), or 200,000 barrels less than in 1883; worth, at 90 cents per barrel, $3,510,000. The total production of all kinds of cement was about 4,000,000 barrels, valued at $3,720,000.

Precious stones.—The estimated value of American precious stones sold as specimens and souvenirs in 1884 was $54,325, and the value of the stones sold to be cut into gems was $28,650; total, $82,975. About $140,000 worth of gold quartz was saved as specimens or made into jewelry and ornaments.

Buhrstones.—The value of the buhrstones yearly made in the United States is about $300,000.

Grindstones.—Dealers estimate the value of the grindstones made in 1884 at $570,000.

Phosphates.—The production of washed phosphate rock in South Carolina during the year ending May 31, 1884, was 431,779 long tons, worth $2,374,784, or 53,399 tons more than in the previous year, with an increase of $104,504 in value. The average spot price, $5.50 per ton, was 50 cents less than in the preceding year. The recent discoveries of phosphate rock in the neighboring States of North Carolina, Alabama, and Florida will probably lead to a still further increase in production. Of manufactured fertilizers, 967,000 short tons, worth $26,110,000, were made in the year ending April 30, 1884, and 1,023,500 short tons, worth $27,640,000, were made in the year ending April 30, 1885.

Marls.—In New Jersey about 875,000 tons, worth $437,500 at the pits, were dug in 1884. In addition, small quantities were produced for local use in some of the Southern States. The production is declining, owing to competition with fertilizers made from phosphate rock, etc.

Gypsum.—In the Atlantic States, from Maine to Virginia, 65,000 long tons of land plaster and 60,000 tons of stucco, total 125,000 tons, were made in 1884, of which nearly all was from Nova Scotia gypsum. The statistics for Michigan have not been reported, but the production did not vary greatly from that in 1883, in which year it was 60,082 short tons of land plaster and 159,100 barrels (of 300 pounds) of stucco. In Ohio 4,217 short tons of land plaster and 20,307 barrels of stucco were produced. There was also a small production in other parts of the country; but the total amount of domestic gypsum used is not known.

Salt.—The production in 1884 was 6,514,937 barrels of 280 pounds (equivalent to 1,824,182,360 pounds, or 32,574,685 bushels, or 912,091 short tons, according to the unit used). The total value, computed on average wholesale prices at the point of production, was $4,197,734. The apparent output was 322,706 barrels greater than in 1883, while the value was $13,308 less; but the production figures do not include a considerable stock on hand in the Onondaga district, not officially reported because not inspected.

Bromine.—The production is estimated at 281,100 pounds, all from the Ohio and West Virginia salt district; worth, at 24 cents per pound, $67,464.

Borax.—Production about 7,000,000 pounds, or 500,000 pounds more than in 1883. The total value, however, was less than that of the product of 1883, being about $490,000 at San Francisco rates, as against $585,000 in 1883.

Sulphur.—No exact statistics. The production was only about 500 tons, worth about $12,000.

Pyrites.—About 35,000 long tons were mined in the United States, worth about $175,000 at the mines. Some 33,500 tons of imported pyrites were also burned, making a total consumption of 68,500 tons.

Barytes.—Full statistics not received. The production is estimated to have been about 25,000 tons; worth, at $4 per ton, unground, at the point of production, $100,000.

Mica.—The production of merchantable sheet mica, not including mica waste, was 147,410 pounds, valued at $368,525.

Feldspar.—The production was 10,900 long tons, or 3,200 tons less than in 1883. Its value at the quarries was $55,112.

Asbestus.—The amount mined was about 1,000 short tons, worth about $30,000.

Graphite.—Production nominal, the supply being drawn from the stock accumulated in 1883.

Asphaltum.—The annual production is about 3,000 tons, having a spot value of $10,500.

Alum.—About 38,000,000 pounds were made in the United States in 1884, or 3,000,000 pounds more than in 1883. At an average spot value of 1⅞ cents per pound, the product was worth $712,500.

Copperas.—The amount made in 1884 was 15,500,000 pounds, worth, at 60 cents per hundredweight, $93,000.

Mineral waters.—The sales of natural mineral waters in 1884 amounted to 68,720,936 gallons, valued at $1,665,490, an apparent increase of 21,431,193 gallons and $526,007 upon the figures for 1883. While the sales are undoubtedly increasing it is possible that the excess in the reported quantity and value of the waters sold in 1884 as compared with 1883 may be partly due to the greater fullness of the returns for 1884. Besides the waters bottled and placed on the market there is a large local consumption, not included in the foregoing figures.

Totals.—As was remarked in the former report, it is impossible to state the total mineral product in any form which shall not be open to just criticism. It is evident that the production statistics of such incongruous substances as iron ore, metallic gold and silver, the spot value of coal mined and the market value of metallic copper after having been transported hundreds of miles, the spot value of a crude substance like unground, unrefined barytes, and the value of a finished product like brick (in which the cost of manufacture is the leading item) cannot well be taken as items in a general summary. The statistics have been compiled with a view to giving information on those points which are of most interest and utility, and are presented in the form usual in the several branches of trade statistics. The result is that the values stated for the different products are necessarily taken at different stages of production or transportation, etc. Theoretically perfect statistics of mineral products would include first of all the actual net spot value of each substance in its crudest form, as taken from the earth; and yet for practical purposes such statistics would have little interest other than the fact that the items could be combined in a grand total in which each substance should be rated on a fairly even basis. The following groupings, therefore, are presented with a full realization of the incongruity of many of the items. The grand total might be considerably reduced by substituting the value of the iron ore mined for that of the pig iron made, by deducting the discount on silver, and by considering lime, salt, cement, borax, etc., as manufactures. It will also be remarked that the spot values of copper, lead, zinc, and chrome iron ore are much less than their respective values after transportation to market. Still, the form adopted seems to be the only one which admits of a comparison of the total values of the mineral products from year to year.

Metallic products of the United States in 1884.

	Quantity.	Value.
Pig iron, long tons, spot value	4, 097, 868	$73, 761, 624
Silver, troy ounces, coining value	37, 744, 605	48, 800, 000
Gold, troy ounces, coining value	1, 489, 949	30, 800, 000
Copper, pounds, value at New York City (*a*)	145, 221, 934	17, 789, 687
Lead, short tons, value at New York City	139, 897	10, 537, 042
Zinc, short tons, value at New York City	38, 544	3, 422, 707
Quicksilver, flasks, value at San Francisco	31, 913	936, 327
Nickel, pounds, value at Philadelphia (*b*)	64, 550	48, 412
Aluminum, troy ounces, value at Philadelphia	1, 800	1, 350
Platinum, troy ounces, value crude at New York City	150	450
Total		186, 097, 599

a Including copper made from imported pyrites.

b Including nickel in copper-nickel alloy.

Non-metallic mineral products of the United States in 1884 (*spot values*).

	Quantity.	Value.
Bituminous coal, brown coal, lignite, and anthracite mined elsewhere than in Pennsylvania .... long tons (*a*)..	73, 730, 539	$77, 417, 066
Pennsylvania anthracite .... do (*b*)....	33, 175, 756	66, 351, 512
Petroleum .... barrels..	24, 089, 758	20, 476, 294
Building stone	....	19, 000, 000
Lime .... barrels..	37, 000, 000	18, 500, 000
Salt .... do....	6, 514, 937	4, 197, 734
Cement .... do....	4, 000, 000	3, 720, 000
South Carolina phosphate rock .... long tons (*c*)..	431, 779	2, 374, 784
Limestone for iron flux .... do ..	3, 401, 930	1, 700, 965
Mineral waters .... gallons sold..	68, 720, 936	1, 665, 490
Natural gas	....	1, 460, 000
Zinc white .... short tons..	13, 000	910, 000
Concentrated borax .... pounds..	7, 000, 000	490, 000
New Jersey marls .... short tons..	875, 000	437, 500
Mica .... pounds..	147, 410	368, 525
Pyrites .... long tons..	35, 000	175, 000
Gold quartz souvenirs, jewelry, etc	....	140, 000
Manganese ore .... long tons..	10, 000	120, 000
Crude barytes .... do....	25, 000	100, 000
Ocher .... do....	7, 000	84, 000
Precious stones	....	82, 975
Bromine .... pounds..	281, 100	67, 464
Feldspar .... long tons..	10, 900	55, 112
Chrome iron ore .... do....	2, 000	35, 000
Asbestus .... short tons..	1, 000	30, 000
Slate ground as a pigment .... long tons..	2, 000	20, 000
Sulphur .... short tons..	500	12, 000
Asphaltum .... do....	3, 000	10, 500
Cobalt oxide .... pounds..	2, 000	5, 100
Total	....	220, 007, 021

a The commercial product, that is, the amount marketed, was only 66,809,356 tons, worth $70, 149,824.
b The commercial product, that is, the amount marketed, was only 30,718,293 tons, worth $61,436,586.
c Year ending May 31.

Résumé of the values of the metallic and non-metallic mineral substances produced in the United States in 1884.

Metals	$186, 097, 599
Mineral substances named in the foregoing table	220, 007, 021
	406, 104, 620
Fire-clay, kaolin, potter's clay, common brick clay, terra cotta, building sand, glass sand, limestone used as flux in lead smelting, limestone in glass making, iron ore used as flux in lead smelting, marls (other than New Jersey), gypsum, tin ore, antimony, iridosmine, mill-buhrstone and stone for making grindstones, novaculite, corundum, lithographic stone, talc and soapstone, quartz, fluorspar, nitrate of soda, carbonate of soda, sulphate of soda, native alum, ozocerite, mineral soap, strontia, infusorial earth and tripoli, pumice-stone, sienna, umber, etc., certainly not less than	7, 000, 000
Grand total	413, 104, 620

The production in 1884, 1883, *and* 1882 *compared.*—Tables showing the quantities and values of the mineral products of the United States in 1883 and 1882 are appended for the sake of comparison. From these it appears that the total value of the metals and minerals produced in 1884 was $39,100,008 less than in 1883, and that the decline in 1883 from 1882 was $3,012,061; that is, the falling off in value began on a small scale in 1883, but was accented in 1884. The net decline, as will be seen by reference to the tables, has been due rather to a depression in price than a decrease in quantity; indeed, several important substances show a decided increase in production, notwithstanding the general dullness of trade. The overproduction, taking the whole field into consideration, has been less than was generally feared.

Metallic products of the United States in 1883.

	Quantity.	Value.
Pig iron, long tons, spot value	4, 595, 510	$91, 910, 200
Silver, troy ounces, coining value	35, 733, 622	46, 200, 000
Gold, troy ounces, coining value	1, 451, 249	30, 000, 000
Copper, pounds, value at New York City (*a*)	117, 151, 795	18, 064, 807
Lead, short tons, value at New York City	143, 957	12, 322, 719
Zinc, short tons, value at New York City	36, 872	3, 311, 106
Quicksilver, flasks, value at San Francisco	46, 725	1, 253, 632
Nickel, pounds, value at Philadelphia (*b*)	58, 800	52, 920
Aluminum, troy ounces, value at Philadelphia	1, 000	875
Platinum, troy ounces, value crude at New York City	200	600
Total	....	203, 116, 859

a Including copper made from imported pyrites. *b* Including nickel in copper-nickel alloy.

Non-metallic mineral products of the United States in 1883 (*spot values*).

	Quantity.	Value.
Bituminous coal, brown coal, lignite, and anthracite mined elsewhere than in Pennsylvania ... long tons (*a*)	68, 531, 500	$82, 237, 800
Pennsylvania anthracite ... do (*b*)	34, 336, 469	77, 257, 055
Petroleum ... barrels	23, 400, 229	25, 740, 252
Building stone	....	20, 000, 000
Lime ... barrels	32, 000, 000	19, 200, 000
Cement ... do	4, 190, 000	4, 293, 500
Salt ... do	6, 192, 231	4, 211, 042
South Carolina phosphate rock ... long tons (*c*)	378, 380	2, 270, 280
Limestone for iron flux ... do	3, 814, 273	1, 907, 136
Mineral waters ... gallons sold	47, 289, 743	1, 139, 483
Concentrated borax ... pounds	6, 500, 000	585, 000
New Jersey marls ... short tons	972, 000	486, 000
Natural gas	....	475, 000
Mica ... pounds	114, 000	285, 000

a The commercial product, that is, the amount marketed, was only 65,030,171 tons, worth $78,036,205

b The commercial product, that is, the amount marketed, was only 31,793,027 tons, worth $71,534,311,

c Year ending May 31.

Non-metallic mineral products of the United States in 1883, *&c.*—Continued.

		Quantity.	Value.
Pyrites	long tons	25,000	$137,500
Manganese ore	do	8,000	120,000
Gold quartz souvenirs, jewelry, etc			115,000
Crude barytes	long tons	27,000	108,000
Precious stones			92,050
Ocher	long tons	7,000	84,000
Bromine	pounds	301,100	72,264
Feldspar	long tons	14,100	71,112
Chrome iron ore	do	3,000	60,000
Graphite	pounds	575,000	46,000
Asbestos	short tons	1,000	30,000
Sulphur	do	1,000	27,000
Slate ground as a pigment	long tons	2,000	24,000
Asphaltum	short tons	3,000	10,500
Cobalt oxide	pounds	1,096	2,795
Total			241,087,769

Résumé of the values of the metallic and non-metallic mineral substances produced in the United States in 1883.

Metals	$203,116,859
Mineral substances named in the foregoing table	241,087,769
	444,204,628
Estimated value of mineral products unspecified	8,000,000
Grand total	452,204,628

Metallic products of the United States in 1882.

	Quantity.	Value.
Pig iron, long tons, spot value	4,623,323	$106,336,429
Silver, troy ounces, coining value	36,197,695	46,800,000
Gold, troy ounces, coining value	1,572,186	32,500,000
Copper, pounds, value at New York City (*a*)	91,646,232	16,038,091
Lead, short tons, value at New York City	132,890	12,624,550
Zinc, short tons, value at New York City	33,765	3,646,020
Quicksilver, flasks, value at San Francisco	52,732	1,487,042
Nickel, pounds, value at Philadelphia (*b*)	281,616	309,777
Antimony, short tons, value at San Francisco	60	12,000
Platinum, troy ounces, value crude at New York City	200	600
Total		219,755,109

a Including copper made from imported pyrites. *b* Including nickel in copper-nickel alloy.

Non-metallic mineral products of the United States in 1882 (*spot values*).

	Quantity.	Value.
Bituminous coal, brown coal, lignite, and anthracite mined elsewhere than in Pennsylvania ... long tons (*a*)	60, 861, 190	$76, 076, 487
Pennsylvania anthracite ... do (*b*)	31, 358, 264	70, 556, 094
Petroleum ... barrels (*c*)	30, 053, 500	23, 704, 698
Lime ... do	31, 000, 000	21, 700, 000
Building stone	....	21, 000, 000
Salt ... barrels	6, 412, 373	4, 340, 140
Cement ... do	3, 250, 000	3, 672, 750
Limestone for iron flux ... long tons	3, 850, 000	2, 310, 000
South Carolina phosphate rock ... do (*d*)	332, 077	1, 992, 462
New Jersey marls ... short tons	1, 080, 000	540, 000
Concentrated borax ... pounds	4, 236, 291	338, 903
Mica ... do	100, 000	250, 000
Natural gas	....	215, 000
Ocher ... long tons	7, 000	105, 000
Soapstone ... short tons	6, 000	90, 000
Crude barytes ... long tons	20, 000	80, 000
Precious stones	....	75, 000
Gold quartz souvenirs, jewelry, etc	....	75, 000
Pyrites ... long tons	12, 000	72, 000
Manganese ore ... do	3, 500	52, 500
Chrome iron ore ... do	2, 500	50, 000
Asbestus ... short tons	1, 200	36, 000
Graphite ... pounds	425, 000	34, 000
Cobalt oxide ... do	11, 653	32, 046
Slate ground as a pigment ... long tons	2, 000	24, 000
Sulphur ... short tons	600	21, 000
Asphaltum ... do	3, 000	10, 500
Corundum ... do	500	6, 250
Pumice-stone ... do	70	1, 750
Total	....	227, 461, 580

a The commercial product, that is, the amount marketed, was only 57,963,038 tons, worth $72,453,797.
b The commercial product, that is, the amount marketed, was only 29,120,096 tons, worth $65,520,216.
c Pennsylvania and New York field only; the outside production was very small.
d Year ending May 31.

Résumé of the values of the metallic and non-metallic mineral substances produced in the United States in 1882.

Metals	$219, 755, 109
Mineral substances named in the foregoing table	227, 461, 580
	447, 216, 689
Estimated value of mineral products unspecified	8, 000, 000
Grand total	455, 216, 689

This total for 1882 has been increased, by corrections and additions, $1,304,283 upon the figure given in the first report of this series, which was $453,912,406.

COAL.

The coal statistics of this volume have been drawn from various sources, including the reports of agents and correspondents of this office, the transportation records of the railroad companies, reports of State mine inspectors and of State geological surveys, etc. Special acknowledgment is due to the excellent work of Mr. F. E. Saward, editor of the *Coal Trade Journal*, whose estimates have been followed in many cases. The compilation has been in charge of Mr. S. C. Armstrong. The papers of Dr. H. M. Chance on anthracite mining, Mr. Stuart M. Buck on coal mining in the Kanawha valley, and Mr. Joseph D. Weeks on the manufacture of coke, which follow this section, should be consulted in connection with it.

PRODUCTION.

A concise statement of the coal output of the United States in 1884, as compared with that of 1883, is here reproduced from the summary, page 1:

The only statistics in which the trade is interested are those relating to the amount of coal which is mined for and reaches the market. There is besides a local and colliery consumption which is usually disregarded in statistics, and which ranges from 5 to 6½ per cent. of the total shipments. Of what may be called the commercial product, the quantities in 1884 were as follows: Pennsylvania anthracite, 30,718,293 long tons; bituminous and brown coal, lignite, and small lots of anthracite mined elsewhere than in Pennsylvania, 66,809,356 long tons; total, 97,527,649 long tons. The spot value of the commercial product was: Pennsylvania anthracite, $61,436,586; bituminous and all other coals, $70,149,824; total, $131,586,410. Including the local consumption, etc., the total product in 1884 may be stated at 106,906,295 long tons; namely, 33,175,756 long tons of Pennsylvania anthracite and 73,730,539 long tons of bituminous and all other coals; and the value at the mines was: Pennsylvania anthracite, $66,351,512; bituminous and all other coals, $77,417,066; total, $143,768,578. The total production (that is, including colliery and local consumption) of anthracite was 1,160,713 long tons less than in 1883, while its value was $10,905,543 less, the disproportionate decline in value being due to a fall of 25 cents per ton in spot price ($2.25 to $2). The total bituminous coal production increased 5,199,039 long tons over that of 1883; but its value was

$4,820,734 less, the average valuation at the collieries having fallen from $1.20 to $1.05. The total output of all coals showed a net gain in tonnage of 4,038,326 long tons and a decline in value of $15,726,277.

The following table shows the commercial output during the last five years, by States and Territories, in long tons. In the case of a few of the smaller items, originally estimated in short tons, it has not been deemed advisable to convert the figures into long tons, the difference being less than the probable error, and the round figures being preferable.

Coal produced in the several States and Territories, not including the local and colliery consumption.

States and Territories.	1880.	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Pennsylvania, anthracite	23,437,242	28,500,016	29,120,096	31,793,027	30,718,293
Pennsylvania, bituminous	19,000,000	20,000,000	22,000,000	24,000,000	25,000,000
Illinois	4,000,000	6,000,000	9,000,000	10,350,000	10,000,000
Ohio	7,000,000	8,250,000	9,450,000	8,229,429	7,650,062
Maryland	2,136,160	2,261,918	1,540,466	2,206,172	2,469,051
Missouri	1,500,000	1,750,000	2,000,000	2,250,000	2,500,000
West Virginia	1,400,000	1,500,000	2,000,000	2,805,565	3,000,000
Indiana	1,100,000	1,771,536	1,976,470	2,560,000	2,260,000
Iowa	1,600,000	1,750,000	3,500,000	3,881,300	3,903,458
Kentucky	1,000,000	1,100,000	1,300,000	1,650,000	1,550,000
Tennessee	600,000	750,000	850,000	1,000,000	1,200,000
Virginia	100,000	100,000	100,000	225,000	300,000
Kansas	550,000	750,000	750,000	900,000	1,100,000
Michigan	75,000	100,000	130,000	135,000	135,000
Rhode Island	10,000	10,000	10,000	10,000	10,000
Alabama	340,000	375,000	800,000	1,400,000	2,000,000
Georgia	100,000	150,000	175,000	200,000	200,000
Colorado	390,183	631,021	947,749	1,097,851	1,008,950
Wyoming	275,000	375,000	631,932	696,151	805,911
New Mexico	(?)	(?)	146,421	188,703	196,924
Utah	225,000	225,000	250,000	250,000	250,000
California	175,000	125,000	150,000	175,000	150,000
Oregon	30,000	30,000	30,000	50,000	50,000
Washington	175,000	175,000	225,000	300,000	300,000
Texas	....	....	....	100,000	100,000
Arkansas	....	....	....	75,000	150,000
Montana	....	....	....	60,000	60,000
Dakota	....	....	....	50,000	40,000
Idaho	....	....	....	10,000	20,000
Indian Territory	....	....	....	175,000	400,000
Total	65,218,585	76,679,491	87,083,134	96,823,198	97,527,649

Including the local and colliery consumption, the figures for the last three years would be as follows, the values being values at the mine:

Total coal output of the United States, 1882, 1883, *and* 1884.

Years.	Anthracite.		Bituminous.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Long tons.		*Long tons.*		*Long tons.*	
1882	31,358,264	$70,556,094	60,861,190	$76,076,487	92,219,454	$146,632,581
1883	34,336,469	77,257,055	68,531,500	82,237,800	102,867,969	159,494,855
1884	33,175,756	66,351,512	73,730,539	77,417,066	106,906,295	143,768,578

THE WORLD'S PRODUCTION OF COAL.

The following table shows the total output of coal for the last calendar years of which statistics are available. With the exception of the figure for the United States, the table has been compiled by the secretary of the American Iron and Steel Association. Long tons of 2,240 pounds are used in giving the statistics of Great Britain, the United States, Russia, and "other countries," and metric tons of 2,204 pounds for all the continental countries of Europe except Russia. As the difference between the long ton and the metric ton is so trifling, it is not necessary to change official figures.

Countries.	Tons.
Great Britain (1884)	160, 757, 815
United States (1884)	106, 906, 295
Germany and Luxemburg (1883)	70, 442, 648
France (1884)	20, 127, 209
Belgium (1884)	18, 041, 000
Austria and Hungary (1883)	17, 047, 961
Russia (1882)	3, 742, 380
Sweden (1882)	250, 000
Spain (1880)	847, 128
Italy (1882)	220, 000
Other countries (1883)	8, 000, 000
Total	406, 382, 436

From this it will be seen that the annual coal production of the United States is now one-fourth of that of the world.

IMPORTS AND EXPORTS.

The following tables show the movement of coal during recent years, as reported by the custom-houses. The values are those declared, and are of course much higher than the "spot" rates which have been used in computing the total annual value of the domestic production.

The tariff from 1824 to 1843 was 6 cents per bushel, or $1.68 per long ton; from 1843 to 1846, $1.75 per ton; 1846, 30 per cent. ad valorem; 1847 to 1861, 24 per cent. ad valorem; 1862 to 1864, $1 per ton; 1865, $1.10; 1866 to 1872, $1.25 per ton; since August, 1872, 75 cents per ton. During the period from June, 1854, to March, 1866, the reciprocity treaty was in force, and coal from the British possessions in North America was admitted into the United States duty free.

The imports are from Australia and British Columbia to San Francisco; from Great Britain to the Atlantic and Pacific coasts, and from Nova Scotia to Atlantic coast ports. The exports are mainly from the lake and Atlantic shipping ports to the Canadian provinces and to the West Indies.

Coal imported and entered for consumption in the United States, 1867 *to* 1884, *inclusive.*

Fiscal years ending June 30—	Anthracite.		Bituminous and shale.	
	Quantity.	Value.	Quantity.	Value.
	Long tons.		*Long tons.*	
1867	....	....	509, 802	$1, 412, 597
1868	....	....	394, 021	1, 250, 513
1869	....	....	437, 228	1, 222, 119
1870	....	....	415, 729	1, 103, 965
1871	973	$4, 177	430, 508	1, 121, 914
1872	390	1, 322	485, 063	1, 279, 686
1873	2, 221	10, 764	460, 028	1, 548, 208
1874	471	3, 224	492, 063	1, 937, 274
1875	138	963	436, 714	1, 791, 601
1876	1, 428	8, 560	400, 632	1, 592, 846
1877	630	2, 220	495, 816	1, 782, 941
1878	158	518	572, 846	1, 929, 660
1879	488	721	486, 501	1, 716, 209
1880	8	40	471, 818	1, 588, 312
1881	1, 207	2, 628	652, 963	1, 988, 199
1882	36	148	795, 722	2, 141, 373
1883	507	1, 172	645, 924	2, 013, 555
1884	1, 448	4, 404	820, 266	2, 558, 164

Coal of domestic production exported from the United States, 1867 *to* 1884, *inclusive.*

Fiscal years ending June 30—	Anthracite.		Bituminous.	
	Quantity.	Value.	Quantity.	Value.
	Long tons.		*Long tons.*	
1867	192, 912	$1, 333, 457	92, 189	$512, 742
1868	192, 291	1, 082, 745	86, 367	433, 475
1869	283, 783	1, 553, 115	....	....
1870	121, 098	803, 135	106, 820	503, 223
1871	134, 571	805, 169	133, 380	564, 067
1872	259, 567	1, 375, 342	141, 311	586, 264
1873	342, 180	1, 827, 822	242, 453	1, 086, 253
1874	401, 912	2, 236, 084	361, 490	1, 587, 666
1875	316, 157	1, 791, 626	203, 189	828, 943
1876	337, 934	1, 869, 434	230, 144	850, 711
1877	418, 791	1, 891, 351	321, 665	1, 024, 711
1878	319, 477	1, 006, 843	340, 661	1, 352, 624
1879	386, 916	1, 427, 886	276, 000	891, 512
1880	392, 626	1, 362, 901	222, 634	695, 179
1881	462, 208	2, 091, 928	191, 038	739, 532
1882	553, 742	2, 589, 887	314, 320	1, 102, 898
1883	557, 813	2, 648, 033	463, 051	1, 593, 214
1884	649, 040	3, 053, 550	646, 265	1, 977, 959

THE COAL FIELDS OF THE UNITED STATES.

ALABAMA.

The portion of the Appalachian coal field covering this State, with an area of 5,530 miles, is the southwestern extremity of that great field. This termination is in the form of a very marked expansion from the narrowness which has characterized the Appalachian system in its passage through Tennessee. The deposits are found in three principal basins, of which much the larger is the Warrior coal field. This field spreads over a large extent of the State and would lie northwest of the line of the Appalachian system as it passes through Tennessee, were it prolonged into Georgia. The area of this field is about 500 square miles. Lying along the southeast border of this, but separated by a narrow belt of older rocks, is the Cahaba coal field, having an area of about 230 square miles, while northeast of this and near it is the Coosa field, covering about 300 square miles. These smaller fields were evidently at one time continuous with the greater ones to the west and belonged to the great Appalachian basin, from which they have been separated by folding, faulting, and erosion. They are narrow and elongated in a northeast and southwest direction. Comparing the geology of Alabama with that of Pennsylvania we find that certain series of strata are very much reduced in thickness. In this State the Coal Measures, however, have suffered no apparent diminution in thickness; they are estimated in round numbers at about 3,000 feet, one section measuring, according to Prof. E. A. Smith, 2,600 feet. The Warrior coal field is divided by Professor Smith into the plateau or table-land region on the north and the Warrior basin proper lying to the south. The southward extension of the anticlinal, which in the northern portion of the State gives rise to Brown's valley, traverses the field as a low ridge and divides the basins into two unequal troughs; of these, the one in the east, which is the narrower and is drained by the Locust fork or Little Warrior river, is the best known, lying as it does between the anticlinal just mentioned and that of Long valley. Between this valley and Locust fork the section already referred to was made by Professor Smith and shows above the Lower Carboniferous limestone about 2,600 feet of Coal Measures, including the Conglomerate at the base; this, from its proximity to the valley and to the railroad, is the part of the field which has been best explored. There are found in this section twelve seams of coal of from 2½ to 7 feet, and having an aggregate thickness of 50 feet; of these, five seams have been mined. The strata are nearly horizontal and affected only by slight undulations. The Pratt seam, the highest in the section, which is now extensively mined about 6 miles west of Birmingham, yields 4½ feet of coal with one shale parting.

To the west of the division just described the development of coal in the region drained by the Big Warrior river is not less considerable, the surveys of Professor Smith and others showing the existence of many excellent seams of good quality, measuring from 3 to 6 feet in thickness.

In its southern part, where the Cahaba field attains its maximum breadth of 12 miles, the measures are regular, and have a dip of from 6° to 10° along the western border, gradually increasing to 12° or 15° near Lily shoals, on the river, and to 45° or more near to its eastern edge, where the strata along the great fault are sometimes nearly vertical. Farther northward, about 30 miles from its southern extremity, where the Cahaba field is reduced to a breadth of 6 miles, the strata are somewhat crushed, and the Upper Measures, which appear farther south, near Montevallo, are wanting. The field is here crossed obliquely by the Alabama North and South railroad, along the line of which, according to Professor Rothwell, are found nine workable beds of coal measuring from 2 to 4 feet in thickness, and giving an aggregate of over 28 feet. In the wider and less disturbed parts of the field, farther south, the coal seams are thicker. On Four-Mile creek the same observer found eight seams with an aggregate thickness of 38 feet, besides four higher seams in the Montevallo beds, equal to 12 feet. Along the eastern border of the field, however, the lower coals will be too deep for profitable mining.

Besides the analyses of coals from this field given by Rothwell, an extended table of analyses of others from the Warrior basin is given by Smith in his report for 1879–1880, and it may be said in general terms that the coals from both these fields are equal to those from the more northern portions of the Appalachian basin. They present the usual varieties in quality and composition, some of them being dry-burning coals, others coking coals with as much as 65 per cent. of fixed carbon, while others contain much more volatile matter.

The coal fields of Alabama, although examined and studied early in the present century and investigated at several times since, were not developed to any extent until during the war. Mines were opened in Alabama to supply coal for the Confederate Government and were worked with success. The excellent qualities of the coal were then clearly demonstrated. Soon after the close of the war several companies were formed to mine coal, but the results were not favorable; the demand had to be built up; the pioneers in the business did not find it profitable; some could not find a market; others struck poor veins of coal, and the result in either case was failure. The day had not come for Alabama coal, nor for the Cahaba, the Newcastle, the Spencer mines, and others. Perhaps the first real success in profitable mining in the State was made by Messrs. T. H. Aldrich & Co., who leased a mine and worked and continued to work the Montevallo coal, a very superior grate coal, fully equal to English cannel coal. In 1872 only 10,000 tons of coal were mined in Alabama. In 1879 the Pratt Coal and Coke Company went to work operating the Pratt seam for steam, coke, and gas purposes, and the Helena seam for grate and coke purposes; this was a new era in the coal business of the State, and much credit is due to Mr. H. F. De Bardeleben, the originator and principal owner of this company, who had the foresight to see the future that awaited the coal industry in Alabama.

Aside from the abundance and excellent quality of the coal in Alabama, a very important circumstance in connection with it is its proximity to the waters of the Gulf of Mexico, with which it can readily be connected by improvement of the rivers draining the coal fields. From Tuscaloosa, which is on the southeastern edge of the Warrior field, there is navigation throughout the year to Mobile, a distance of 355 miles. As appears from a report of the United States Engineers to the War Department submitted to Congress in 1880, there is between Tuscaloosa and Sipsey fork, in the Warrior basin, in a distance of 92½ miles, a rise of about 160 feet. A system of dams and locks, with chambers 145 by 30 feet, would suffice to establish water communication from this point, in the heart of the coal field, to Mobile throughout the year, for an estimated cost of $400,000. Barges laden with cotton, coal, and lumber have, it is said, for many years been sent down this way during seasons of high water.

The Alabama river is navigable from Montgomery or Wetumpka to Mobile; and the Cahaba river, which drains the Cahaba field and falls into the Alabama a little above Selma, can in like manner, according to official report, be made navigable at a cost of $500,000. Railroad facilities, while for a long time insufficient, are also good, four prominent roads now passing through the coal districts. They are the Louisville and Nashville, the Georgia Pacific, the East Tennessee, Virginia and Georgia, and the Alabama Great Southern. The scope of work has, consequently, widened, instead of confining itself to the river banks, as was formerly the case. Six years ago the Louisville and Nashville road hauled only 2,000 tons of Alabama coal. Now there are as many tons mined each day in the Birmingham district alone. The demand for Alabama coal is far in excess of the supply. Its introduction into New Orleans and other southwestern markets has met with immense favor. Many new mines are starting into operation, and branch railways are being constructed, so that the outlook for the coal industry in this State is very good. The appended analyses will serve to show the character of the coal:

	Pratt.	Williams.	Jaggers.	Lost creek.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Volatile matter	31.48	26.18	29.00	33.79
Fixed carbon	61.60	66.02	56.53	57.00
Water	1.50	1.52	3.09	2.26
Ash	5.42	6.28	11.38	6.95
	100.00	100.00	100.00	100.00
Sulphur	.92	.60	.57	.73

Production of coal in Alabama since 1873.

Years.	Long tons.	Years.	Long tons.
1873	40,000	1879	200,000
1874	45,000	1880	340,000
1875	60,000	1881	375,000
1876	100,000	1882	800,000
1877	175,000	1883	1,400,000
1878	200,000	1884	2,000,000

ALASKA.

Anthracite has been several times reported from various parts of Alaska. An analysis of a specimen of the Cook's Inlet coal showed only 0.37 per cent. less combustible matter and 0.66 per cent. more ash than good Pittsburgh bituminous coal, which difference would be offset by the 1.09 per cent. additional moisture in the latter coal. The amount of sulphur is less than in either of the two best Tertiary coals on the line of the Central Pacific railroad, and the amount of moisture is claimed to be lower than in any other American coal of which analyses have been tabulated. A good coal has been found also on Admiralty island, almost equal in quality to the Wellington coal of Vancouver island. A bed of coal represented to be anthracite was recently discovered at Saint John's bay, 17 miles north of Sitka, a sample from which used on one of the United States vessels in those waters was pronounced a fair steam coal.

ARIZONA.

In Apache county, Arizona, vast measures of coal exist, but are yet undeveloped. The coal region embraces the northern division of Apache and that portion of Yavapai county north of the Little Colorado river. This coal bed also extends into New Mexico on the east and Utah on the north. Mr. C. P. Stanton, who visited the fields, writes:

"Close to Fort Defiance there is a vein 9 feet thick, and it seems to possess all the qualities of excellent bituminous coal, and to rank next to anthracite for domestic purposes. I see no reason why it should not be pre-eminently useful for generating steam and for smelting purposes. This description will apply to all the coal in the Arizona coal basin. The next great bed of coal is situated almost 20 miles northwest from the Moqui villages. It is 23 feet thick, and boldly crops out for a distance of 3 miles. The coal is close, compact, and forms a very hot fire. It resembles in external appearance the Pennsylvania bituminous coal."

The Atlantic and Pacific railroad passes a few miles south of this deposit in New Mexico, and the company uses the coal for locomotive fuel. The main belt is nearly 50 miles north of the line.

Mr. Patrick Hamilton, author of "Resources of Arizona," says:

"On Deer creek, a tributary of the Gila, in Pinal county, bituminous coal of an excellent quality has been discovered. The extent of the deposit is about 4 miles long by 2 miles wide. The veins are from 3 to 8 feet thick. The coal makes excellent coke, and for domestic purposes is said to be unequaled."

The late survey of the San Carlos reservation brings these coal beds within its limits, and the work of development has consequently been stopped.

ARKANSAS.

The coal field of Arkansas covers twelve counties and has an area which has been variously estimated to be from 9,000 to 12,000 miles. It is a portion of the great Missouri field, but projects into Arkansas, not from Missouri, but from that portion of the field lying in Indian Territory, and while broad as it enters the State, narrows rapidly to a point. The outcrops, showing coal from 4 to 7 feet thick, are nearly all found on the south side of the Arkansas river, in Sebastian county, and cover a territory from 12 to 18 miles wide, east and west, and 30 to 35 miles north and south. On the north side of the river the coal shows a thickness of only a foot or two until Ozark, 30 miles from the west line of the State; there it approximates 4 feet, but rapidly thins until it runs out about 100 miles from the Indian Territory line, on the north side of the Arkansas river. The Spadra semi-anthracite is the only coal that is known in market to any extent. An account of its location, etc., will be found in the first volume of this series. As far as mining operations are concerned but little has been done. The Little Rock and Fort Smith Railroad Company mine to a small extent 30 or 40 miles east of Fort Smith, taking coal to Little Rock and other points. A corporation under the name of the Arkansas Coal and Mining Company, however, has purchased 3,000 or 4,000 acres of coal land, 25 miles south of Fort Smith, and may inaugurate extensive operations. There is not yet much local demand.

CALIFORNIA.

Although it is easy to find coal at many localities in the Coast range from one end of the State to the other, as well as at certain points in the western foothills of the Sierra Nevada, it generally happens either that its quality is poor, or its quantity is small, or else that it is situated in the heart of the mountains so far from market that the cost of transportation alone would far exceed the value of the coal. The development of mines which, under other circumstances, might be worked has also been interfered with by the facility with which imported coal can be secured on the Pacific coast.

The fact that many ships are constantly coming to San Francisco, the main point of delivery for wheat cargoes, is in favor of comparatively cheap freights for foreign coals; and cargoes of coal are thus brought from Australia and Great Britain at very low rates. Owing, however, to the number of losses of ships during the past two years from their cargoes of coal taking fire, it is hardly probable that any lower rates of freight will be secured, as the insurance companies are now considering the advisability of still further increasing the already large premiums for such cargoes. It is now difficult to secure shipments of Scotch splint, West Hartley, and similar coals, as the insurance companies are demanding double the rates of 1883, on the ground that, on account of the great combustibility of these coals, they are not adapted to long voyages. Owing to these tendencies the coal-mining industry on the Pacific coast has been stimulated during the last two years, and greater activity, with a consequent increased production, has resulted.

In 1883 the receipts of coal in San Francisco amounted to 899,301 tons, of which the Mount Diablo, California, mines produced only 76,162 tons. These mines, combined with the coast collieries, produced of the total amount but 322,335 tons. During the first six months of 1884, however, the consumption of coal increased more than 96,000 tons over the similar period in 1883. During these six months too these importers of foreign coal are said to have made heavy losses. Thus incited to greater efforts, some of the coast collieries increased their product considerably in the period mentioned, the Tacoma and Seattle collieries having shipped 50,000 tons in excess of the amount produced in the same period in 1883. Again, a colliery in Nanaimo, British Columbia, which did not yield anything in 1883, sent down 45,240 tons in the first six months of 1884. The following statistics show the receipts of coal at San Francisco for the past three years:

Receipts of Pacific coast coal at San Francisco.

Mines.	Location.	1882.	1883.	1884.
		Short tons.	*Short tons.*	*Short tons.*
Mount Diablo	Mount Diablo, California	113, 356	76, 162	77, 485
Southport	Coos Bay, Oregon	12, 866		
Seattle	Newcastle, Washington	150, 000	139, 600	125, 000
Renton	do	24, 000	20, 476	32. 413
Newport	Coos Bay, Oregon			*a*5, 000
South Prairie	Tacoma, Washington		15, 871	*b*22, 910
Carbon Hill	Carbon Hill, Washington	64, 745	140, 135	122, 060

a Not worked till December. *b* Shipments began in June.

The various sources from which California derived her coal supplies during the past two years are as follows:

Total receipts of coal at San Francisco in 1883 *and* 1884.

From—	1883.	1884.
	Short tons.	*Short tons.*
British Columbia (Wellington and Nanaimo)	128, 503	291, 546
Australia	174, 143	190, 497
English and Welsh	131, 355	108, 808
Scotch	21, 942	21, 143
Eastern (Cumberland and anthracite)	43, 861	38, 124
Seattle	139, 600	125, 300
Carbon Hill	140, 135	122, 060
Mount Diablo (three mines)	76, 162	77, 485
Renton, Newport, and South Prairie	43, 600	60, 413
Total	899, 301	1, 035, 076

In computing these annual imports into California the arrivals at Wilmington (the seaport of Los Angeles) are included, amounting in 1884 to 67,000 tons of foreign coal.

While numerous other deposits in the State have of late years been developed, and are attaining some commercial importance, the Mount Diablo field continues to be the principal home source of supply. The extent of this field may be stated in broad terms to be some 10 or 12 miles along the line of outcrop of the beds running through the northern part of township 1 north, range 1 east, and the northwestern and central portions of township 1 north, range 2 east, Mount Diablo meridian.

By the phrase "Mount Diablo coal field," as here used, however, must be understood not merely the actually productive region but the whole extent of the belt through which there has been found some definite evidences of probability that the beds were once continuous, or nearly so, and within which sufficient discoveries have been made to lead to the expenditure of any considerable sums of money in explorations and attempts to develop new mines. The area within which the mines have hitherto been profitably worked, however, is far more limited in extent. It lies among the higher hills in the western portion of the belt above described, and includes a distance of only about 2½ miles along the strike of the beds, from the west limits of the Black Diamond Company's workings in the northeast quarter of section 7, where the beds either split up, or run out, or become too much crushed and broken to pay for working, to the most eastern limits of the Pittsburgh Company's workings in the southwest quarter of section 3 and the northwest quarter of section 10, where they are stopped by the wall of a great fault which intervenes between them and Stewart's mine on the east. The Central (*i. e.*, Stewart's) mine is not here included within the profitably productive limits, for the simple reason that while it has produced considerable coal, its shipments having been sometimes as high as a thousand tons per month, it is more than probable that its production has been at a loss instead of a profit to its owners.

Within the limits thus indicated, the chief openings of the mines, as well as the dwellings of the miners and other buildings, are, owing to the topography of the country, concentrated at two villages, Nortonville and Somersville, which are about a mile apart. Each of these villages lies at the head of a deep cañon running northerly to the edge of the San Joaquin plain. Down each cañon runs a railroad of standard gauge, the distance from each village to the plain being about 3 miles. The railroads, after emerging from their respective cañons, continue northwardly across the plain, which is about 3 miles in width, to the San Joaquin river, terminating at points of shipment on that stream.

The coal beds which have been profitably worked in the Mount Diablo district are three in number, and are known, respectively, as the "Clark vein," the "Little vein," and the "Black Diamond vein." Of these the Clark vein is the highest in stratigraphical position; next in order below it comes the Little vein; while the Black Diamond vein is the lowest and underlies both the others. The beds lie nearly parallel with each other, all dipping to the north, and at the immediate localities of the villages, both of Nortonville and Somersville, the amount of dip is from 30° to 32°.

In the Clayton tunnel, at Nortonville, as the level distance from the floor of the Clark vein south to the roof of the Black Diamond vein is 696 feet, and the dip here being about 31°, it follows that the total thickness of the strata, including the Little vein, between the Clark and Black Diamond veins, is at this locality about 359 feet. At certain points the level distance between the beds is somewhat less than it is here, while in other places it is considerably greater. This is due mainly to changes in the degree of dip of the beds, though it is more than probable that the actual thickness of the strata between them also varies somewhat at different localities.

Mount Diablo coal has been mainly used for steam coal in San Francisco and on the steamers of the bay; but it is a lignite of poor quality, and, owing to its sulphur, is disliked for domestic purposes.

Commencing to produce in 1860, the Mount Diablo mines have since turned out about 100,000 tons a year. Their yield for the past two years, however, has been about 76,000 tons per year, and a material decrease is expected, if not an entire cessation of production. The supply of other coal of better quality is increasing, and competition will probably soon become too severe for a profitable working of these deposits. This has already gone so far that the mines are at present closed, and there is some doubt as to their starting again.

The coal fields of Ione valley, Amador county, which produce an inferior coal, are being rapidly developed. They are known to extend from Lancha Plana to Buckeye valley, a stretch of about 20 miles in Amador county, and into Placer county, where the Lincoln coal mines are being worked. The coal is found in a narrow channel of varying width. On various spots on the Grant Company's property holes have been bored, and coal is found at a depth of 60 feet from the surface. The seam varies from 4 to 20 feet in thickness, and the practice so far has been that when the layer has been worked out the mine has been abandoned without exploring to greater depths. The coal seam rests upon a mixture of white clay and sand, the underlying formation being unknown. The deepest point at which boring operations have been pushed is 125 feet. Coal is being mined at three distinct places: from two mines near Ione City, one owned by the Ione Coal Company, or more generally known as the Railroad Company's mine, and the other by Dwight Younglove. The former is shipping an average of 100 tons per day, and the shipments of the latter have averaged 50 tons per day. This coal is delivered on the cars at Ione for $1.50 and $2 per ton, the higher price being for stove coal for household use. At the Younglove mine a tunnel has been run from the side hill, which has penetrated the coal channel a distance of 250 feet, and how far beyond lies the western limit of the deposit has yet to be determined.

The Lancha Plana coal mine, owned by Murray & Waddell, and which has been idle for some time, owing to want of means to work it to advantage, has recently been leased for a period of twenty years to Mr. Gregory, of Sacramento. The coal found at this point is said to be of a better quality than the Ione coal. The new proprietors have started in to work the property on a large scale. The mine is 5 miles distant from the terminus of the San Joaquin and Sierra Nevada narrow-gauge railroad. At present the coal is hauled by team to the railroad depot at a cost of $2 per ton. By the cars it is hauled to tidewater and from thence shipped to San Francisco and other points. It can be laid down in San Francisco for $6 per ton, which will leave the mine owners a fair margin of profit. It is the intention of the new management to build a railroad side track to the coal mine, which will greatly reduce the cost of transportation to market.

The Ione Coal Company is opening up a new mine about 3 miles north of Ione. Coal has been encountered at a depth of 55 feet, and also a strong body of water, which is giving considerable trouble to control.

The Ione Valley coal frequently receives the name of ionite, from its peculiar composition. This name was given it by Mr. Samuel Purnell, of the Central Pacific Railroad Company. Mr. Purnell describes it as follows:

"When first found it contains 50 per cent. of water, but when air-dried it floats on water, the specific gravity being about 0.9. It melts to a pitch-like mass which burns easily with a dense black smoke, having a resinous aromatic odor, and with a yellow flame. Ionite contains 13 per cent. of impurity, principally silica and alumina. Streak reddish yellow, fracture irregular, luster none. When pulverized, water suspends a portion of the clay in the mineral. It is partly soluble in cold alcohol, more so in boiling alcohol, giving a brown solution. On addition of water no precipitate is deposited, but the solution becomes permanently of a milky color. Very soluble in ether, forming a brownish black solution; on adding water a brown tarry substance is obtained, very inflammable, and which, while burning, gives off the odor of burning sealing wax; wholly soluble in chloroform, except the clay or ash, forming a brownish black solution; poured into water a brown oil falls to the bottom; partly soluble in cold, more so in boiling oil of turpentine, forming a wine-red solution; on concentration of the solution crystals of paraffine are separated; almost wholly insoluble in cold or boiling petroleum naphtha; subjected to dry distillation a brown tarry oil passes over mixed with green colored water. Ionite is found in considerable abundance at the original locality, and I have found it in lignite beds in San Benito county. It will be more carefully studied in the future and will perhaps be found valuable otherwise than as a fuel."

Among California discoveries announced of late, the deposit known as the McIntosh & Cheney, in San Diego county, is seemingly the most important. A tunnel which has been carried into this deposit a distance of 200 feet shows a solid vein of coal of from 4 to 7 feet in thickness, but little mixed with slate or other foreign matter, and not much different from the Mount Diablo coal. This coal can be easily mined, and as it burns well and can be afforded at a low price, the output of the mine, amounting to several hundred tons, has met with ready sale to consumers in the neighborhood. Should this deposit prove permanent, it will greatly benefit that part of the country, which is almost destitute of timber. Coal indications of a similar kind have also been met with during the past year or two in Mono and Los Angeles counties, the importance of these finds being magnified through their occurrence in sparsely wooded districts. Coal signs occur in many other parts of the State, but in few instances has enough work been done upon them to indicate their probable value.

COLORADO.

The deposits of coal in Colorado are of great extent, and are found in almost every portion of the State. The coal area has been variously estimated at from 20,000 to 50,000 square miles. The known and partially developed coal fields cover about 1,500 square miles, while the area of the Laramie, Fox Hills, and Colorado Cretaceous formations, which are coal-bearing, comprises about one-third of the surface of the State, or approximately 35,000 square miles.

Coal mining in Colorado is yet in its first stages; but the development of the mines is keeping pace with the growth of the State. The rapid increase of the manufacturing and railroad interests has of late created a large demand for fuel, which has caused the opening of a number of new mines, and the resumption of work at many old and abandoned workings. However, except in the immediate neighborhood of Golden, no depth has as yet been attained, only those veins which crop on the surface having been opened to any extent.

The coal fields of the northernmost portion of Colorado are known to occupy quite a wide extent of territory, but remain as yet undeveloped through lack of railroad facilities and a market for the coal. The best known coal veins are embraced in the Crafton property, containing 6,720 acres in the North park, Grand county. The coal here occurs in the Laramie formation, and is similar in almost every respect, as to character and mode of occurrence, to the coal in the Boulder and Weld county fields. It is a lignite of ordinary quality, and occurs in three distinct veins. The principal openings are the Coal Hill, Red Hill, No. 1, and No. 3. In the Coal Hill mine the coal exposed is about 15 feet thick, breaks in lumps of all sizes, and is free from earthy matter, but contains considerable quantities of iron pyrites. The following are analyses of two specimens:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	18.35	8.82
Volatile matter	32.20	41.56
Fixed carbon	41.90	41.17
Ash	6.45	6.00
Sulphur	1.10	2.45
	100.00	100.00

The specific gravity of No. 1 is 1.364. The color of the ash is gray.

The Red Hill vein is about three-quarters of a mile distant, and shows 27 feet of coal, including two 6-inch bands of shale. The coal is similar to that exposed in the Coal Hill mine. The following analyses show its composition:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	15.20	10.50
Volatile matter	33.30	37.30
Fixed carbon	48.00	50.30
Ash	3.50	1.90
	100.00	100.00

The specific gravity of No. 1 is 1.356. The color of the ash is gray.

One mile northeast of the Red Hill mine is the No. 1 mine. The vein here is the widest in the region, showing 32 feet of coal in 33 feet of vein material. The coal breaks in thin flakes, perpendicular to the plane of bedding, and shows the woody structure of lignite. The following are analyses of two specimens of this coal:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	12.25	13.20
Volatile matter	34.75	9.30
Fixed carbon	38.75	72.00
Ash	14.25	5.50
	100.00	100.00

The specific gravity of this coal is 1.424. The source of the No. 2 sample is not absolutely known. It shows a remarkable superiority to all other coal here.

The No. 3 mine is a little further northeast, and the vein appears to be the same as that exposed at the No. 1 mine, being probably exposed here by a synclinal fold. An open cut shows 11 feet of coal, the composition of which is shown below:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	15.70	14.60
Volatile matter	38.25	25.60
Fixed carbon	40.55	53.50
Ash	5.50	6.30
	100.00	100.00

Its specific gravity is 1.360.

Coal is also found at various points on the divide between the North and Middle parks and in the Middle park, but lack of demand has prevented the development of the veins.

North of the divide and east of the mountains whence Denver draws its principal supply of fuel, coal is found in Jefferson, Boulder, and Weld counties, in which region some twenty mines are being worked.

The leading ones are the Marshall, Fox, Welch, Boulder Valley, Northrop, Stewart, Superior, Mitchell, Garfield, Briggs, Star, Baker, White Ash, Murphy, Ralston, Black Diamond, and Mount Carbon.

The coal from this district is a free-burning lignite of jet-black color, high luster, and of a specific gravity averaging about 1.33. As a rule, it is wholly destitute of any fibrous or woody structure, and contains less than 0.4 per cent. sulphur. The proportion of ash varies from 2 to 8 per cent., averaging about 4.5. It is in general use for domestic purposes, for locomotives, and for blacksmithing. The veins which are worked vary in width from 3 to 12 feet and average about 6 feet.

The following analyses show the characteristics of the coal from the various mines of northern Colorado:

	Golden.		From the Murphy mine on Ralston creek, Jefferson county.	From the Marshall mine at Langford, Boulder county.	From the Erie mine at Erie, on Coal creek, Weld county.
	No. 1.	No. 2.			
	Per cent	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water	13. 43	13. 67	13. 83	12. 00	14 80
Volatile matter	37. 15	34. 75	35. 88	26. 00	34. 50
Fixed carbon	45. 57	47. 58	44. 44	59. 20	47. 30
Ash	3. 85	4. 00	5. 85	2. 80	3. 40
	100. 00	100. 00	100. 00	100. 00	100. 00

The coal mines of northern Colorado stand second in the list of producers, their output being exceeded only by the mines of southern Colorado, which section includes the mines of Las Animas county.

All the coal mined in northern Colorado is used on the divisions of the Union Pacific railroad in Colorado, the Denver, Utah and Pacific railroad, and in Denver and the agricultural mining towns north of the divide. The capacity of the various mines at Erie, Canfield, Louisville, and Langford, on January 1, 1883, has been estimated by Major McDowell, of Erie, to be as follows:

Localities.	Daily capacity.
Erie and Canfield:	*Tons.*
Star mine	100
Jackson mine	150
Northrop mine	150
Briggs mine	12
Garfield mine	36
Stewart mine	150
Superior mine	18
Mitchell mine	200
Erie and Canfield—Continued.	*Tons.*
Erie mine	200
Louisville:	
Louisville or Welch mine	500
Langford:	
Marshall mine (2 slopes)	300
Fox mine (1 slope)	100
Black Diamond mine	25

The middle division includes the counties of Douglas, Park, El Paso, and Fremont.

The Douglas mine, the only one opened in Douglas county, is situated west of Sedalia. It is connected with Sedalia station by a branch of the Denver and Rio Grande railway. The vein is in the upturned edge of the Laramie rocks and varies in width from 8 to 14 feet, the coal being free from bone and slate throughout its thickness. It is a lignite of fair quality, resembling the Franceville coal. It is opened by a shaft 160 feet deep on the vein, which dips at an angle of 80°. Four hundred and thirty feet of side drifts have been run on the vein. Depth shows that the coal is materially improving, and a new shaft will be sunk to a depth of 500 feet. The coal is consumed by towns along the Rio Grande railway in Denver, and to some extent on the railroad. Twenty-two men are employed, and the output in 1885 will be much increased. In 1883, during November and December, the production was 1,500 tons. The production in 1884 has been 9,000 tons.

The Denver and New Orleans mine at Franceville, in El Paso county, has been opened for a little more than two years, or since the completion of the Denver and New Orleans road, has been actively worked, and is a large producer of lignite. The mine is situated about ten miles east of Colorado Springs, and the coal occurs in the rocks of the Laramie period. The vein is 10 feet wide, with fireclay roof and slate floor. The property contains 160 acres, and is opened by a main drift 1,700 feet long. About 10 acres have been explored by drifts, while the area mined is less than 5 acres. The coal is an average lignite of jet black color, and showing a rather high percentage of ash. Of the 10 feet of coal only 8 are mined, 2 feet being left as a roof. The coal is quite clear of bone, and no firedamp is found in the mine. The following is an analysis of this coal:

	Per cent.
Water	12.90
Volatile matter	29.10
Fixed carbon	4[illegible].00
Ash	12.00
	100.00

The entire fuel supply of the Denver and New Orleans railway is furnished by this mine. The railway consumes about 15 per cent. of the whole output. Production began in July, 1882, and the output up to January 1, 1883, was 23,694 tons. During 1883 the output was 54,416 tons, and in 1884, 56,070 tons. Production in 1884 was considerably decreased by the general strike throughout the coal-mining regions in October and November. The fuel supply of Colorado Springs is derived mainly from these mines, while large quantities of the coal are sold for domestic consumption in Denver at the pooled price for northern coals, $4.50 per ton.

In Park county the coal mines are near Como, and are owned by the Union Coal Company. They produce a good coking coal, the greater part of which is consumed by the railway company. The fuel supply of Leadville comes largely from these mines, which are not far distant.

The bank is faulted in several places, and is expensive to work. The seam is known as the Lechner coal, and varies from 5 to 6 feet in width.

The principal mines in Fremont county are the Coal Creek, Oak Creek, Rockvale, and Williamsburg mines, and are owned by the Colorado Coal and Iron Company, and by the Atchison, Topeka and Santa Fé Railroad Company. Two separate beds are worked, the upper averaging about 3½ feet, and the lower from 3¾ to 4 feet in width. The coal is semi-bituminous, and is sometimes mixed with bituminous coals from El Moro to make coke. Its composition is shown by the following analysis, which is taken from a report by Mr. C. M. Rolker:

	Per cent.
Moisture	5.03
Volatile matter	35.85
Fixed carbon	50.97
Ash	8.15
	100.00
Sulphur	1.04
Specific gravity	1.363

The composition of other coals from the same section and taken from the two Oak Creek mines is shown by the following analyses from the company's books:

	No. 1 mine.		No. 2 mine.	
	Top coal.	Bottom coal.	Top coal.	Bottom seam.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	6.59	6.72	6.90	6.19
Volatile matter	35.92	34.76	36.42	36.28
Fixed carbon	52.72	52.70	52.00	51.14
Ash	4.77	5.82	4.68	6.39
	100.00	100.00	100.00	100.00

The coal ranks first in the State for all domestic purposes, and is largely used in Denver, while Cañon City and Pueblo derive their supply almost entirely from these mines.

The southern division includes the counties of Las Animas, Huerfano, La Plata, and Dolores, and is by far the largest producing district in Colorado. The coal of Las Animas county is as a rule bituminous, and large quantities are made into coke for the use of smelters in Colorado and New Mexico.

The El Moro or Engle mine at El Moro, which is owned by the Colorado Coal and Iron Company, is the largest producer in the State. The coal bed varies from 6 to 10 feet in thickness, and a general average of 7½ feet can be assumed. The coal produced is a true bituminous coal and makes an excellent coke, and is also used for making gas. A sample across the vein, excluding bony parts, gave the following analysis:

	Per cent.
Moisture	.95
Volatile matter	29.82
Fixed carbon	56.41
Ash	12.82
	100.00
Sulphur	.41

The following are three other analyses of this coal:

	No. 1.	No. 2.	No. 3.
	Per ct.	*Per ct.*	*Per ct.*
Water	.26	1.66	1.34
Volatile matter	29.66	34.48	35.79
Fixed carbon	65.76	60.08	54.75
Ash	4.32	3.78	8.12
	100.00	100.00	100.00

The present capacity of the mine is about 1,000 tons per day, but this amount can readily be increased. The mine produced from 1879 to January 1, 1884, 783,000 tons of coal. The property owned by the Colorado Coal and Iron Company here is estimated to contain 8,124,000 tons of good coal.

The Cucharas deposit is situated near Walsenburg in Huerfano county. One vein only has been heretofore developed. This is 7 feet thick, and the coal is very similar to the Cañon City coal, affording an excellent fuel for steam and domestic purposes. This coal is said to be the best for locomotive use mined in the State, and has been largely used by the Burlington and Missouri River railroad's engines.

Its composition is shown by the following analyses:

	Four-foot seam.	Seven-foot seam.
	Per cent.	*Per cent.*
Water	3.23	2.97
Volatile matter	40.93	40.08
Fixed carbon	49.54	48.67
Ash	6.30	8.28
	100.00	100.00
Sulphur	.62	.65

The mines at Starksville are operated by the Trinidad Coal and Coking Company for the Atchison, Topeka and Santa Fé railway, and have now a capacity of 600 tons per day, which can easily be increased. The vein worked is 6 feet thick and the coal makes an excellent coke. The company owns eighty coke ovens.

The mines of Las Animas, Huerfano, and Fremont counties are mainly owned and operated by the Colorado Coal and Iron Company, a corporation which is closely allied to the Denver and Rio Grande Railroad Company.

A large proportion of the area of La Plata county is underlaid by extensive beds of coal which occur in the Fox Hills horizon. Only the portion of the coal field near Durango has yet been explored, and here the exploration has been limited by the small local demand in Durango and Silverton. About one-quarter of the fuel supply of the Durango branch of the Denver and Rio Grande railway is derived from these mines. While it is generally claimed that these veins are of great thickness, they are so broken by seams of slate and bony coal that the workable width of the veins is only slight. The Mammoth vein is estimated to be from 60 to 90 feet thick, but the coal is so mixed with seams of slate that the thickest stratum of workable coal is only 5 feet 6 inches thick. Other seams of the same bed range from 3 feet down to 20 inches in thickness. In the bed there are three or four workable seams only. The coal contains a good deal of sulphur and the mines are troubled with firedamp. The dip of the bed varies from almost 60° to 40°. The natural inclination of the Fox Hills group is probably about 7° to 8°. Upon this belt four openings have been made, the California, Carbonaria, Peerless, and Fairmount mines. The California mine has been worked but slightly and produced scarcely anything in 1884. The Carbonaria mine is about 2½ miles from Durango and is owned by the Durango Coal and Land Company. This mine supplies the ten beehive coke ovens owned by the New York and San Juan Smelting Company with slack for coking. The coal mine formerly supplied the town of Durango with a large portion of its fuel, but the local demand is now mainly supplied by the Adams Coal Mining Company.

The Peerless mine has produced no coal. The Fairmount has been idle for two years.

About 1 mile from the Mammoth is another series of veins varying from 2 to 5 feet in thickness. The beds are separated by layers of sandstone, fireclay, and shale, varying from 25 to 100 feet in thickness. A mine was opened upon this belt by Mr. J. A. Porter in 1883, the product being an excellent bituminous coal, well adapted for coking, but the thinness of the vein rendered work unprofitable and it was closed in the spring of 1884.

Upon the same belt is the City coal bank, which produces a semi-bituminous coal of good grade. The vein is from 2 feet 6 inches to 3 feet in thickness. Near this mine is the Black Diamond mine, which produces a good coal. The mine has only been worked during the fall and winter months of each year. Messrs. Wixon & Chandler and Gallegan Brothers also own mines in this belt. Near them is the Champion mine, on which work was actively begun about September 30, 1884, when the owners began supplying the Denver and Rio Grande railway. The Adams Coal Mining Company is also mining considerable quantities of coal. Its mine and the Black Hawk mine are situated near the Champion.

The production for 1884 in La Plata county was:

Mines.	Short tons.
Adams Coal Mining Company	10,000
Driscoll & Hampson	1,150
Champion	2,561
Knapp & Thornton	337
Other mines, about	5,000
Total	19,048

The coal field of Dolores county is some 9 miles from Rico, and has not been opened very extensively. Its area is about 5 by 10 miles. The bed lies on both sides of the Dolores river and about 750 feet above the stream. It has been opened by the Pasadena Reduction Company, the Grand View Smelting Company, and J. W. Parks. The Pasadena opening shows a seam from 32 to 36 inches in width, the Grand View seam is from 18 to 22 inches thick, and that of J. W. Parks is about 20 inches.

The production in 1884 was:

	Short tons.
Pasadena	1,200
Grand View	1,500
J. W. Parks	800
Total	3,500

All these coals coke well, but the percentage of ash is from 18 to 25.

The northwestern division embraces Gunnison, Pitkin, Summit, Routt, and neighboring counties. The most extensive developments are at Crested Butte, Gunnison county. In some respects this is the most important coal bed in the State, producing the best coking coal; and is with the exception of the limited beds in the Los Cerillos mountains, New Mexico, the only true anthracite coal found west of the Alleghanies.

The bituminous coal occurs in four veins, 4 feet, 5 feet, 6 feet, and 10 feet respectively in thickness, the 10-foot vein only being opened to any great extent. The following analyses show the composition of the different varieties of Crested Butte coal:

	No. 1.	No. 2.	No. 3.	No. 4.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
Water	3.70	.72	1.10	.44
Volatile matter	30.97	23.44	23.20	24.17
Fixed carbon	61.07	71.91	72.60	72.30
Ash	4.47	3.93	3.10	3.09
	100.21	100.00	100.00	100.00

The coal from the bituminous mines at Crested Butte is now exclusively used in gas-making in Pueblo, Denver, Leadville, Gunnison, and other towns in Colorado.

The Colorado Coal and Iron Company, since the opening of the Denver and Rio Grande railroad to Salt Lake City, is shipping considerable quantities of coal and coke from Crested Butte to Utah. Small quantities of Crested Butte coal are used east of the continental divide, but the principal part of the product is consumed in coke making and for fuel in Gunnison and other western counties. The only anthracite coal known to occur in Colorado is found in Gunnison county, on Slate creek, near Crested Butte, west of Irwin, and on Anthracite creek, which is a tributary of the North fork of the Gunnison river. The field near Crested Butte is of limited extent, anthracite coal being known to occur only over an area of about two square miles, but the extensive development of the Anthracite Mesa mine has made this the most prominent and well-known field in Gunnison county. The developments hitherto made have been in this mine alone, which is opened by a main drift over 1,300 feet long. Of the 640 acres owned by the company only about 25 acres have been explored by drifts and entries, of which perhaps 10 acres have been mined. There are three or four veins in the field, of which only one has been opened. The vein is about 4 feet 5 inches in thickness on the average, and dips 7° to the south. It is underlaid by from 3 inches to 1 foot of broken anthracite and slate. The roof is sandstone. The composition of the coal, which is a true anthracite, is shown by the following analyses:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	1.588	1.55
Volatile matter	5.862	4.74
Fixed carbon	89.780	89.89
Ash	2.770	3.82
	100.000	100.00

The following is an average of a number of analyses made at different times:

	Per cent.
Water	1.20
Volatile matter	5.16
Fixed carbon	90.24
Ash	3 40
	100.00

From the underlying and narrower vein a specimen of coal showed:

	Perc cnt.
Water and volatile matter	5.17
Fixed carbon	90.65
Ash	4.18
	100.00

The mine was opened in 1882, but the product was trifling during that year. In 1883 the production during seven months amounted to

10,191 tons. During five months the mine was closed, and on August 25, 1884, was leased to the Colorado Fuel Company, of Denver. Up to that date the product in 1884 was 3,871 tons, and from August 25 to January 1, 1885, it amounted to 12,038 tons, making the total for the year 15,909 tons, and for the entire period of working, 26,100 tons. The coal is sold in Gunnison for $6 per ton, and in Denver for $8.50 per ton of 2,000 pounds. The number of men employed December 1, 1884, was 75. The coal is conveyed from the mine to the breaker by a tram 1,750 feet long and there loaded on the cars of the Denver and Rio Grande railway. The breaker owned by the company is modeled after the ordinary anthracite breaker used in Pennsylvania and has a capacity of 300 tons in 10 hours. The work of the mine is seriously interfered with during winter months by the heavy snowfalls characteristic of the section.

To the south of the town of Irwin and some seven or eight miles west from the Anthracite Mesa is a continuation of the same vein of anthracite coal in a field of some considerable extent. The vein of anthracite here has been opened and prospected in various places, but as yet there has been no production beyond a few tons annually for local use. The field here is probably much larger and possibly better than the Anthracite Mesa field. Down Anthracite creek and on various tributaries of the North fork of the Gunnison, anthracite coal is known to occur over a large extent of territory, but the quality of the coal is generally inferior and no good vein has been opened.

This anthracite field is particularly remarkable from the fact that it is, with the exception of a limited field in Sante Fé county, New Mexico, the only locality where true anthracite is known to occur in any quantity in the West. In quality it is excellent, and, where used for domestic purposes, is generally preferred to any other coal. It burns well, and contains quite small quantities of ash. Its superior quality is not generally known, but its use is continually growing.

The Cutler banks in Uncompahgre county, on the divide between the Cimarron and the Uncompahgre, produce a medium grade lignite, suitable especially for domestic and railway purposes. There are four principal veins, 21 feet, 14 feet, 12 feet, and 6 feet in thickness. They have as yet been only partially opened, but their proximity to the Utah extension of the Denver and Rio Grande railroad will cause their early development. The following analysis shows its composition:

	Per cent.
Water	7.26
Volatile matter	43.42
Fixed carbon	41.72
Ash	7.60
	100.00

This coal does not coke.

A vein of semi-anthracite coal occurs in the cañon of the Uncompahgre, about five miles north of Uncompahgre park. The vein is about 2½ feet in width, and some small amounts of the product are freighted to Ouray. The composition is shown below:

	Per cent.
Water	1.86
Volatile matter	10.70
Fixed carbon	77.32
Ash	10.12
	100.00

The anthracitic character of this coal is thought to be due to the igneous dikes in the vicinity of the outcrops.

The Cow Creek mine, near Ouray, and on a branch of the Uncompahgre river, shows a vein over 10 feet in width of a very fair lignite coal. The mine was opened in 1883, but no coal was extracted. There is no market for the coal except in Ouray, which requires about 60 tons per month. The completion of a branch railway up the valley of the Uncompahgre to the North San Juan mines will bring this mine into prominence as a producer. The output in 1884 was 400 tons, all of which was sold in Ouray.

Coal veins have been opened on Rock creek, in Pitkin county, and some of the coal has been made into coke for the use of the Aspen smelter. No statistics have been obtainable, but the production in 1884 did not exceed 1,000 tons. The coal is not very clean, but portions of the vein yield a fair coke. The local demand in Aspen is exceedingly small.

The principal coal mines of Colorado are owned or controlled by the railway companies which enter the State. The companies operating on the largest scale and the corporate name under which they transact their mining operations are the following:

Denver and Rio Grande Railway: Colorado Coal and Iron Company.

Union Pacific Railway: Union Coal Company.

Burlington and Missouri River Railroad: Colorado Fuel Company.

Atchison, Topeka and Santa Fé Railroad: Cañon City and Trinidad Coal and Coking Companies.

Denver and New Orleans Railroad: New Orleans Coal Mining Company.

Denver, Utah and Pacific Railroad: Mitchell Coal Mining Company.

Of these, the largest is the Colorado Coal and Iron Company, which has its headquarters at South Pueblo, and controls mines in Fremont, Las Animas, Huerfano, and Gunnison counties. It owns all of the important coking coal veins in the State except that of the Trinidad Coal and Coking Company. Small coking veins are also said to be owned by individuals at Crested Butte and Rico. The production of coal by this company is shown by the following table:

Years.	Short tons.	Years.	Short tons.
1873	12,187	1879	120,102
1874	18,092	1880	221,378
1875	15,278	1881	350,944
1876	20,316	1882	511,239
1877	44,410	1883	602,396
1878	82,140	1884	450,808

The greater portion of this coal is consumed by the Rio Grande railway, the rest being used by the company's steel works and for making coke. The operations of this company have been seriously curtailed in 1884 by strikes, which lasted from August 4, almost uninterruptedly, until December 22. The comparative production of its different mines can be seen by the following statement of production in 1883:

Mines.	Short tons.
Coal Creek mine, Fremont county	112,679
Oak creek, No. 1, Fremont county	6,126
Oak creek, No. 2, Fremont county	54,786
El Moro mine, Las Animas county	277,577
Walsen mine, Huerfano county	82,391
Cameron mine, Huerfano county	5,298
Crested Butte mine, Gunnison county	63,539
	602,396

The Union Coal Company embraces the mines owned by the Union Pacific Railway Company. This company owns mines mainly in northern Colorado, and the greater part of its production is consumed by the railway for fuel. The principal mines and their production in 1883 is as follows:

Localities.	Short tons.
Boulder valley, Weld county	12,753
Northrup, Weld county	18,112
Welch, Boulder county	97,138
Como, Park county	60,140
Baldwin, Gunnison county	13,052
	201,195

The production from these mines in 1884 was lessened because of the general strikes, and was 195,041 tons, the only decrease having been in the Welch and Northrup mines, amounting to 37,019 tons.

The Colorado Fuel Company has as yet no producing mines, its fuel supply coming from others. It consumes the greater portion of the production of the Cameron and Walsen mines of the Colorado Coal and Iron Company. It also controls by lease the anthracite mines of the Anthracite Mesa Mining Company at Crested Butte.

The coal properties of the Atchison, Topeka and Santa Fé Company, and their production in 1883 are as follows:

Mines.	Short tons.
Trinidad mines, Las Animas county	109, 190
Cañon mines, Fremont county	106, 854
Total	216, 044

The Denver and New Orleans Railway owns the mines at Franceville, El Paso county, the production in 1883 being 54,416 tons. The Mitchell mine is in Weld county and is operated by the Denver, Utah and Pacific Railway. The production of the mine in 1883 was 18,119 tons.

The total production of coal by railways in 1883 was 1,093,170 tons, leaving but 136,523 tons as the output of other corporations.

The production of coal in Colorado has steadily increased since the mines in Boulder and Jefferson counties were first opened. In the decade from 1860 to 1870 considerable quantities of coal were mined for domestic uses in Golden, Denver, Boulder, Black Hawk, and Central, the principal supply coming from the mines near Golden, and on Ralston creek, 10 miles north. The Marshall coal bank assumed importance as a producer in 1865, although previous to that time the ranchmen in the neighborhood had hauled away small quantities of coal. The completion in the summer of 1870 of the Denver Pacific railroad from Cheyenne to Denver, the Kansas Pacific, and the Colorado Central from Denver to Golden, created a large demand upon the mines of Jefferson and Boulder counties. The completion of the Boulder Valley railroad from Brighton to Boulder, in 1873, opened to market the mines of Weld and Boulder counties, where the present coal-mining towns of Erie and Canfield now stand.

The following table shows the growth of coal mining near Golden:

Years.	Short tons.	Years.	Short tons.
1864	*a* 500	1875	*b* 23, 700
1865	*a* 1, 200	1876	*ab* 28, 750
1866	*ab* 6, 400	1877	*a* 30, 000
1867	*ab* 17, 000	1878	31, 400
1868	*ab* 10, 500	1879	33, 435
1869	*ab* 8, 000	1880	36, 500
1870	*ab* 13, 500	1881	37, 625
1871	*ab* 15, 860	1882	46, 264
1872	*ab* 14, 200	1883	21, 100
1873	*ab* 14, 000	1884	21, 000
1874	*ab* 15, 000		

a Estimated.
b Includes product of Marshall mine, Boulder county.

The amount of coal shipped from the mines in the vicinity of Erie and Canfield, from the completion of the Boulder Valley road in 1872 to 1877, is shown by the following figures, furnished by the auditor of the Denver Pacific railroad:

Years.	Short tons.	Years.	Short tons.
1872	54, 340	1875	59, 860
1873	43, 790	1876	68, 600
1874	44, 280		

The estimates of the production of the northern division for the years 1877 and 1879 are taken from Fossett's "Colorado," which is generally accepted as an authority in statistical matters. The average thickness of all the beds composing the Jefferson County coal field is from 30 to 35 feet. These beds have been explored to a depth of over 600 feet—the deepest coal mining in the Far West. At this depth the coal is dense, hard, free from mechanical moisture, and of superior quality as fuel, resembling anthracite in many of its properties.

Coal production of Colorado from 1864 *to* 1884.

Years.	Localities.	Short tons.	
1864	Jefferson and Boulder counties		500
1865	Jefferson and Boulder counties		1, 200
1866	Jefferson and Boulder counties		6, 400
1867	Jefferson and Boulder counties		17, 000
1868	Jefferson and Boulder counties		10, 500
1869	Jefferson and Boulder counties		8, 000
1870	Jefferson and Boulder counties		13, 500
1871	Jefferson and Boulder counties		15, 860
1872	Jefferson and Boulder counties	14, 200	
	Weld county	54, 340	
			68, 540
1873	Jefferson and Boulder counties	14, 000	
	Weld county	43, 790	
	Las Animas and Fremont counties	12, 187	
			69, 977
1874	Jefferson and Boulder counties	15, 000	
	Weld county	44, 280	
	Las Animas and Fremont counties	18, 092	
			77, 372
1875	Jefferson and Boulder counties	23, 700	
	Weld county	59, 860	
	Las Animas and Fremont counties	15, 278	
			98, 838
1876	Jefferson and Boulder counties	28, 750	
	Weld county	68, 600	
	Las Animas and Fremont counties	20, 316	
			117, 666
1877			160, 000
1878	Northern division	87, 825	
	Central division	73. 137	
	Southern division	39, 668	
			200, 630
1879	Northern division	182, 630	
	Central division	70, 647	
	Southern division	69, 455	
			322, 732
1880	Northern division	123, 518	
	Central division	136, 020	
	Southern division	126, 403	
	Northwestern division	1, 064	
	Unreported mines	50, 000	
			437, 005
1881	Northern division	156, 126	
	Central division	174, 882	
	Southern division	269, 045	
	Northwestern division	6, 691	
	Unreported mines	100, 000	
			706, 744
1882	Northern division	300, 000	
	Central division	243, 694	
	Southern division	474, 285	
	Northwestern division	43, 500	
			1, 061, 479

Coal production of Colorado from 1864 *to* 1884—Continued.

Year.	Localities.	Short tons.	
1883......	Northern division:		
	Mines near Erie and Canfield	80,165	
	Louisville	97,138	
	Langford	45,500	
	Golden	21,100	
			243,903
	Central division:		
	Mines near Sedalia	1,500	
	Franceville	54,416	
	Como	60,140	
	Cañon City	280,345	
			396,401
	Southern division:		
	Mines near Trinidad and El Moro	400,929	
	Walsenburg	87,689	
	Durango and Rico	12,689	
			501.307
	Northwestern division:		
	Mines near Crested Butte	....	87,982
	Total, 1883	....	1,229,593

The coal production of Colorado in 1884 was greatly lessened by repeated and extended strikes among coal miners, lasting from August 4 to the end of the year. The company suffering the heaviest loss has been the Colorado Coal and Iron Company, but almost every coal operator in the State has felt the effects of the strikes to a greater or less degree. The production of the mines of the northern portion of the State would otherwise have shown a great increase consequent upon the growth of Denver and of railway and manufacturing interests.

The production in 1884 was as follows:

	Short tons.
Northern division:	
Mines near Erie and Canfield	102,955
Hornsville	73,327
Langford	56,000
Golden	21,000
	253,282
Central division:	
Mines near Sedalia	9,000
Franceville	56,070
Como	63,123
Cañon City	167,995
	296,188

	Short tons.
Southern division:	
Mines at Trinidad and El Moro	402,060
Walsenburg	61,798
La Veta	583
Durango and Rico	19,424
	483,865
Northwestern division:	
Mines at Crested Butte	51,538
Ouray	400
Baldwin	28,842
Anthracite coal	15,909
	96,689
Total	1,130,024

The number of men employed in coal mines is estimated to be about 1,750. The wages paid vary from 60 cents to $1.25 per ton. The value of Colorado's product in 1883 may be averaged at about $2.25 per ton at the mines, a total of $2,766,584.25. The value of the output in 1884, at the same price per ton, is $2,542,554.

DAKOTA.

Western Dakota shows over a vast extent of country the rocks of the Laramie formation, and a large portion of this Territory is probably underlaid by seams of coal of varying thickness and quality, but similar to those of the eastern coal field of Montana. As in all the northwestern Territories, lack of surveys renders all estimates of the area of the coal-bearing territory valueless. In 1874 the Government Land Office estimated the coal-bearing area at 100,000 square miles, but investigations have shown that this estimate is much too great, and the probability is that only a comparatively small section is coal-bearing. Although some deposits are known to occur north of the Black Hills and elsewhere, the coal development has so far been confined to two localities, Sims and Little Missouri, where the Northern Pacific Coal Company has opened mines. The Little Missouri mine is near the western boundary of the Territory, on the line of the Northern Pacific. The coal produced here is a poor lignite. The mine has been closed since February 1, 1884, and probably will not be worked again. During January, 1884, the production was but 323 tons of coal. The coal has been superseded entirely for use on locomotives by the greatly superior coals found elsewhere on the Northern Pacific, notably at Bozeman, Montana.

GEORGIA.

The coal field of Georgia is found in the northwestern corner of the State, and is of comparatively small extent, covering only 170 square miles. It is formed by the passing across of a portion of the Appalachian field on its way from Tennessee into Alabama. Some few works mine the coals, which are similar to those found in adjacent parts of Tennessee and Alabama. The product is small, being estimated at 200,000 tons for 1884.

IDAHO.

Bituminous coal and lignites, some of which burn well, have been found at many points in Idaho. In the Squaw Creek country, 20 miles from Boisé City, the outcrop of good coal is found over a district 12 miles square. The coal has been tested and has proved excellent. A company has been formed to carry on mining operations in the district, and several contracts have already been placed for it. This coal may possibly be used extensively at the smelters in the vicinity of Wood River.

ILLINOIS.

This State contains the greater part of the Illinois coal field, a very large proportion of its surface being underlaid by the Coal Measures. The field is longest from northwest to southeast, the eastern side spreading over a considerable portion of Indiana and the southeastern extremity passing across the Ohio into Kentucky. The Coal Measures, as in the Appalachian system, contain repeated alternations of sandstones, shales, bituminous slate, thin bands of limestone, and seams of coal, with the under clays which usually accompany them. In southern Illinois they attain an aggregate of from 1,200 to 1,400 feet, while in the northern portion of the State their entire thickness does not exceed 600 or 800 feet. The Conglomerate sandstones at the base of the true Coal Measures must be considered with the latter, for the reason that they contain, as in other States, coal seams of workable thickness, which shade into the true Coal Measures in such a manner that it is difficult to fix any dividing line between them. In the southern part of the State these Conglomerate Coal Measures are from 200 to 300 feet in thickness, and at some points contain well-defined coal seams, though generally local in their character.

The report of the Bureau of Labor Statistics for 1882 presents much valuable information in regard to the coal field of the State. From it we learn that within the limits of the Coal Measures there have been discovered sixteen different seams of coal. These seams vary in quality, in continuity, and in thickness, and are never all found at any one place; yet some of the most persistent of them pervade large areas, are of good minable thickness, easily worked, and sufficiently near the surface to be readily reached. At the same time there is a marked degree of uniformity in the distribution of these productive seams throughout the State, so that coal may be said to be generally prevalent.

In the geological classification these seams of coal are numbered upward, the No. 1 bed lying at the base of the formation and the No. 16 at the top. The strata bearing all those seams below No. 9 are designated as the Lower Measures, and those above and inclusive, the Upper Measures. The former underlie nearly the whole body of the State, and being carried to a great depth by the dip of the strata in the middle and southeastern portions of the State, are there overlaid by the Upper Measures, which occupy perhaps a half of the whole field. The most prolific and persistent seams, and the only ones which are extensively mined, are those of the Lower Measures, which are also the most universal. Of these Nos. 1, 2, 5, 6, and 7 are the most conspicuous and productive.

No. 1 is the characteristic coal of Rock Island and contiguous counties, in the northwestern borders of the field; and it is not elsewhere so extensively mined, though found in Warren, McDonough, and other counties. No. 2, however, is more generally distributed. It has its fullest development in the "Big Muddy" region, where it sometimes attains a thickness of 8 feet at or near the surface. In this region the earliest coal mines of the State were developed. The same seam also appears in the opposite extremity of the State, in the Braceville and Wilmington districts, with a thickness of 3 feet and a depth below the surface of about 100 feet. Again it is found at La Salle, at a great depth, and is known as the "third vein" coal; and at Minonk, in Woodford county, it is about 2½ feet thick, and is reached at a depth of 552 feet below the surface. Its latest discovery has been at Mattoon, in Coles county, where it has been reached by the deepest and most costly shaft in the State, at a depth of 904 feet. At all these points this seam is noticeable for its excellence.

In the central portion of the State No. 5 is the commercial coal, and in Sangamon and Macoupin counties it lies at a depth ranging from

200 to 400 feet, and attains a thickness varying from 5 to 8 feet. This seam also produces the greater portion of the coal in Peoria county, where it is found nearer the surface, and about 4½ feet thick. No. 5 is also the so-called "second vein" at La Salle. Of late it has been discovered and opened at Niantic, in Macon county, where it is 5½ feet thick and 365 feet deep, and is also found at Decatur, with a thickness of 4½ feet and a depth of 612 feet, and at Pana, in Christian county, at a depth of 714 feet and 7½ feet thick. It constitutes the rich deposit at Astoria, in Fulton county, and appears also in the south end of the State, both in Williamson and Saline counties, and wherever found is a seam of good body and quality.

Seam No. 6 is the distinguishing coal of the Belleville district, embracing several counties tributary to Saint Louis. It is from 6 to 7 feet thick at the surface, but, following the inclination of the strata in a general dip to the east, is carried in Clinton county to a depth of 400 feet, and in the vicinity of Centralia, Marion county, to a depth of 600 feet. In Saint Clair county, however, it is generally within 150 feet of the surface. This seam is also identical with that at Kewanee and Sheffield, on the north; it is associated with No. 5 in the mines at Bloomington, and makes a valuable outcrop in the vicinity of Danville, Vermillion county.

The phenomenal seam, however, is No. 7, which in Williamson county, in the southern extremity of the State, presents an outcrop 10 feet thick, and an average thickness in the mines at Carterville, about 60 feet below the surface, of 9 feet. This seam also shows a thickness of 7 feet in the Danville district, where it is extensively mined and stripped, and again appears as the "first" or upper vein of La Salle, and is associated with No. 5 in the outcrop on the Ohio river. The Streator has also been identified as No. 7. This seam is distinguished wherever found by the character of its partings. Late discoveries at Streator disclose a seam 9 feet in thickness, with two partings, whereas in the old workings the seam is 6 feet, with one parting. These partings give the deposit the appearance of three seams in one, but it is believed to be nearly one seam.

The seams peculiar to the so-called Upper Measures, numbered from 9 to 16, are found in those parts of the State where the Upper Measures prevail, though rarely of sufficient importance to be worked. They are frequently intersected by the deeper shafts in different localities before the lower coals are reached, and thus their character and relative positions are defined.

At the La Salle shafts, Nos. 9, 12, and 13 are present, in addition to Nos. 2, 5, and 7, which are the workable beds. These upper seams range from 6 to 12 inches in thickness. In Macoupin county Nos. 8, 9, and 10 appear above the principal seam from 10 to 15 inches thick; while in the counties lying south and east of the center of the State, Nos.

14, 15, and 16 sometimes attain a thickness of 20 or 30 inches, and when lying near the surface possess some economic value.

In this part of the State the main seams of the Lower Measures are carried by the inclination of the strata to a great depth; but the belief is entertained, and confirmed by observation and experience, that the greater cost involved in reaching these lower seams will be compensated for by the greater uniformity and purity of the coal when obtained. This has proved to be the case in the interesting and costly test for coal which has just been successfully consummated at Mattoon. At this point the shaft has been pushed to a depth of 904 feet, but at that depth has disclosed 3½ feet of coal entirely free from the prevailing impurities of Illinois coal. At Pana and at Decatur valuable seams have also been discovered at great depth.

On the extreme northeastern border of the coal fields in Grundy, Will, and Livingstone counties the measures contain a single seam of coal, averaging about 3 feet in thickness. In the vicinity of Morris this seam is about 30 feet below the surface, and is easily accessible but somewhat variable in quality. This seam has been reached at other places in the same part of the State by boring, and its proximity to Chicago renders it of importance. It is supposed to be the equivalent of the seam found at Murphysborough, in Jackson county, or No. 2 of the general section.

Analyses of some Illinois coals.

Designation.	Water.	Ash.	Volatile matter.	Fixed carbon.
Bloomington, McLean county	7.90	4.96	34.02	53.12
Blair Bluff, Henry county	12.60	9.90	28.96	48.54
Barclay, Sangamon county	10.80	17.10	27.32	44.78
Carbondale, Jackson county	6.36	7.40	26.40	59.84
Catlin, Vermillion county	7.80	12.70	31.08	48.42
Danville, Vermillion county	9.60	14.64	31.20	44.56
DuQuoin, Perry county	8.86	7.00	23.54	60.60
Elmwood, Peoria county	7.60	9.50	27.60	55.30
Farmington, Fulton county	8.52	11.72	29.28	50.48
Grape Creek, Vermillion county	9.74	10.60	28.34	51.32
Kewanee, Henry county	15.60	7.14	27.60	49.66
Lincoln, Logan county	10.92	14.84	27.60	46.64
Lombardville, Stark county	9.42	7.46	31.38	51.74
Mount Carbon, Jackson county	6.12	2.70	24.68	66.50
Oglesby, La Salle county, second vein	12.12	7.72	30.84	49.32
Oglesby, La Salle county, third vein	10.06	3.72	30.34	55.88
Peru, La Salle county, second and third veins	10.30	4.54	33.90	51.26

The following statements are presented by the State Bureau of Statistics of Labor for the year ending July 1, 1884:

Number of counties producing coal	49
Number of mines and openings of all kinds	741
Number of employés of all kinds	25,575
Number of tons of coal mined, 1884	10,101,005
Aggregate value of the same at the mines	$13,164,976
Average value per ton for the State at large	$1.30
Average number of days of active operations in the year	200
Average price per ton paid for mining	$0.82
Number of kegs of powder used	144,378
Number of men killed	46
Number of men injured so as to lose time	197
Number of tons mined for each life lost	219,587
Number of employés of all kinds for each life lost	556

A comparison with the report of the bureau for the year ending July 1, 1883, shows that the number of mines and openings of all kinds has increased largely, being given for the latter year as 639, and 741 for the year ending July 1, 1884. The analysis of the character of the several mines, as indicated by their output, however, shows that the increase in the number of mines producing more than 10,000 tons a year is only nine, the increase indicated by the total number of mines being almost entirely in mines whose annual product is less than 10,000 tons. The average value of coal per ton at the mines, for the State at large, as computed by the bureau, was, for the year ending July 1, 1884, $1.30, as opposed to the average of the previous year, $1.46. The average working time of all the mines in the State for the same year is computed by the bureau as 200 days. The following is a statement of the coal production of Illinois since 1873:

Years.	Long tons.	Years.	Long tons.
1873	3,500,000	1879	3,500,000
1874	3,000,000	1880	4,000,000
1875	3,500,000	1881	6,000,000
1876	3,500,000	1882	9,000,000
1877	3,500,000	1883	10,350,000
1878	3,500,000	1884	10,000,000

INDIANA.

Indiana contains part of the southeastern end of the Illinois coal basin, the lines of the basin passing on across the Ohio some distance to their terminus in western Kentucky. The productive coal lands of the State have an area of about 250,000 acres, the coal-producing rocks being found in the counties of Posey, Vanderburg, Warrick, and Spencer; the western parts of Perry and Crawford; in Gibson, Pike, Dubois, Knox, Daviess, Martin, Sullivan, Greene, and Clay; the western part of Owen, and in Vigo, Parke, Vermillion, Fountain, and Warren, with a projection in a narrow band of Coal Measure rocks (conglomeratic sandstone), underlaid by thin beds of Keokuk limestone and Knobstone shales of the Lower Carboniferous group, extending from the northern part of Warren county in a northeasterly direction across Benton, and terminating near Rensselaer, in Jasper county, where the Conglomerate is massive. It is probable that this projection is not continuous, but interrupted at intervals.

The development of the coal fields of Indiana has been somewhat recent. The existence of coal in the State has long been known, but for many years, except for blacksmithing purposes, it scarcely found a market, the supply being chiefly brought from Pennsylvania. The establishment of the State Geological Survey and the publication of its reports did much to call attention to the abundance of coal in the State and its excellent quality. Since the work of the survey has been going on the value of the coal lands has risen greatly, and the coal is used to a very large extent by railroads and manufacturing establishments and for household purposes, not only in Indiana, but in many neighboring

States, extensive shipments being made as far west as Kansas. The output has increased 300,000 tons a year for the last six years. The most important, from a manufacturing point of view, is the block coal, which is chiefly found in three veins, the lower block 3 feet 8 inches thick, the main block 4 feet 4 inches, and the upper block 1 foot 10 inches. This is an admirable coal, and in many respects is peculiar to the State. What the celebrated English chemist Mushet said about a certain Welsh coal is equally applicable to the block coal of Indiana. To the purity of splint coal it unites all the softness and combustibility of wood, and the effects produced by it in the blast furnace, either as to the quality or quantity of iron, are claimed to exceed everything in the manufacture of that metal with charcoal. From careful analyses it is ascertained that this coal gives from 56 to 62 per cent. of fixed carbon, and a small amount of water and of ash. Dr. E. T. Cox, the geologist, gave this coal an exceptional character as an iron-smelting fuel, and reports a ton of pig iron as being made with 4,250 pounds of block coal.

The coal in Clay county is favorably known as an iron-smelting fuel, and its qualities are thus described: "There are two veins of coal, the upper averaging about 3 feet 10 inches in thickness and the lower averaging about 4 feet. The roof is principally sand rock, slate, and slate and sand rock mixed. Fire and potter's clay of good quality underlie the coal. The average depth to the first vein is about 45 feet from the surface, and the second or lower vein is found at an average depth of 75 to 80 feet. The coal is free from slate and sulphur. It burns freely, and leaves a soft, fine, white ash, similar to wood ash, and no clinkers." For domestic and steam purposes the coal is largely used in all the cities and towns both of this and adjoining States, as transportation facilities are of the most extended character.

In the block-coal zone of the Indiana coal fields there are as many as eight seams of non-coking coal, four of which are of good workable thickness over a portion of the field. These are I, G, F, and A, which together have a maximum thickness of 15 feet; and by including the other four seams we have 6 feet more, making a total of 21 feet of block coal.

The coal of Parke county is favorably reported on for the manufacture of iron. It is a block coal, averaging 5 feet in thickness, weighing 77 pounds to the cubic foot, and gives by analysis 62.5 fixed carbon, 31.00 volatile matter, 4.05 water, and 2 per cent. of ash. The estimated area is about 300 square miles of workable coal.

The "upper block," at Washington, in Daviess county, is extensively mined, and meets with a ready market at Saint Louis and all the towns on the Ohio and Mississippi railroad. Its specific gravity is 1.294; a cubic foot weighs 80.87 pounds; by analysis it yields: Fixed carbon, 60.00; ash, 4.50; volatile matter, 35.50. The coal worked is known as L, a 5-foot seam of bituminous, an excellent coking coal, free from impurities, and which may be handled and stocked without much loss. It has been used for gas-making at Saint Louis, and is a 3-foot 10-inch seam of very pure coal, jet black, of cubical fracture, and bears a good reputation as a fuel for general uses.

The following analyses show the character of the Indiana coal:

Localities.	Fixed carbon.	Volatile matter.	Water.	Ash.
Fountain county	54.5	36.0	5.0	4.5
Vanderburg county	48.5	42.0	3.5	6.0
Warwick county	49.5	41.5	3.5	5.5
Posey county	51.0	39.5	4.0	5.5
Sullivan county	55.0	40.0	3.5	1.5
Daviess county	53.5	36.0	5.5	5.0
Vermillion county	46.0	44.0	5.5	4.5
Parke county	46.5	46.0	4.0	3.5
Montgomery county	52.0	41.5	3.0	3.5
Clay county	61.5	32.5	3.5	2.5
Owen county	57.5	38.5	2.0	2.0
Greene county	63.0	29.5	7.0	0.5

The following statement shows the production of coal in Indiana since 1873:

Years.	Long tons.	Years.	Long tons.
1873	1,000,000	1879	1,196,490
1874	812,000	1880	1,500,000
1875	800,000	1881	1,771,536
1876	950,000	1882	1,976,470
1877	1,000,000	1883	2,560,000
1878	1,000,000	1884	2,260,000

INDIAN TERRITORY.

The Coal Measures of this Territory are known to cover about 12,000 square miles, although how much of this may be productive is not known. At Savanna and Lehigh are located the coal mines which supply the great system of roads operated by the Gould combination. These are the chief developments in the Territory and are mining a large amount of coal.

The following analysis shows the composition of the coal:

	Per cent.
Water	2.90
Volatile matter	36.79
Carbon	36.41
Ash	3.90
	100.00

IOWA.

The Coal Measures of Iowa have been divided into three groups, the Upper, Middle, and Lower Coal Measures. The Upper Measures occupy the southwestern corner of the State and carry but one seam of coal, which averages about 18 inches in thickness; the middle Coal Measures outcrop chiefly along the line of the Des Moines river, throughout a belt of country some 50 miles in width, passing through some nine counties. These measures contain all the larger beds of coal, and in fact the most of the coal of any commercial importance found within the limits of the State. The line within which the outcrop of the Lower Coal Measures is found is very irregular, but in general does not depart far northeast of the line of the Des Moines river. The line of outcrop of the Lower measures is of course the limit of the coal of Iowa, with the exception of a small deposit in Scott county, 8 miles west of Davenport. Here there is a small district of almost one township containing a seam of coal averaging 3 feet in thickness. In this district are located ten mines (one slope and nine shafts), the deepest of the latter being 64 feet.

In the main coal field there are eight counties which have coal ranging from 5½ to 9 feet in thickness, while several of the others have within their limits veins from 3 to 4 feet thick. The development of the coal industry in Iowa, as in Indiana, has been quite recent. A few years since the State was considered to have but little coal of importance. With a great spread of railroad facilities, however, development of the coal fields has been going on rapidly, and the production of the State will no doubt rise greatly within the next few years.

The following statement shows the production in Iowa since 1873:

Output of coal in Iowa.

Years.	Long tons.	Years.	Long tons.
1873	350,000	1879	1,600,000
1874	500,000	1880	1,600,000
1875	1,000,000	1881	1,750,000
1876	1,500,000	1882	3,500,000
1877	1,500,000	1883	3,881,300
1878	1,500,000	1884	3,903,458

KANSAS.

The workable coal beds in the State of Kansas, so far as discovered, are limited to a very small portion of the State, covering an area of about 17,000 square miles. The same three divisions occur here as in Iowa and Missouri, and the measures are about 2,000 feet in thickness. In these measures twenty-two different seams of coal have been found, varying from a few inches to 7 feet in thickness; ten of these are over a foot thick. In some portions of the State the coal is mined by stripping, and is of superior quality, being rich in bituminous matter, and is a very good gas and blacksmithing coal, being free burning and containing no sulphur. The largest amounts have been mined near Fort Scott, where it is very near the surface, but workings extend along the southeast portion of the State, in Cherokee and Crawford counties. In the latter county this vein has been discovered 120 feet deep, and is now being mined at that depth. The market for this coal is found in many cities in eastern Kansas and Nebraska and western Iowa and Missouri. The railroad facilities are good.

In Osage county coal is mined throughout a district about 30 miles long by 8 or 10 wide. The vein is light, averaging about 15 to 18 inches, but at one place runs from 20 inches to 3 feet thick. The coal is bituminous, but a little drier and lighter than the southeastern Cherokee coal. The mines are not deep, most of them being less than 50 feet. There are nearly 100 shafts in Osage county alone, and a large number of men find employment. This coal is marketed in the central part of the State, diverging in all directions from the mines, the railroads taking a large proportion.

At Leavenworth is found the deepest coal of the State, 712 feet from the surface. The vein is 22 inches thick, and extends south to Lansing, the location of the penitentiary, where it is worked by the convicts, under the authority of the State. These are the only two points where the coal is mined, but it seems probable that the coal deposits cover a very large portion of the country. The coal is good, hard, with considerable luster, and a little inclined to be brittle. The works mining this coal at Leavenworth are the most extensive in the State.

In Franklin and Neosho counties thin veins of coal are found similar to the Osage coal. In Cloud county a vein of lignite of inferior quality is found in several places, from 20 to 60 feet from the surface, and averaging about 2 feet in thickness. This coal is mined chiefly for local use. It is found also in Ellsworth, Russell, Lincoln, and Mitchell counties.

A very good vein of coal over 3 feet thick has recently been discovered at Omio, Jewell county. A company has been formed which has put down a shaft in the vein and is preparing to do a considerable business.

There are but few counties in the eastern half of the State that have no coal. Several which have no mines of commercial importance have many workings which produce coal for local use, generally of inferior quality.

The production of coal in Kansas was largely increased last year, owing, in part, to the strikes in Colorado. The following figures show the amount of coal produced during 1869 and since 1880, the figures for 1869 being from the census report:

Years.	Tons.	Years.	Tons.
1869	32, 938	1882	750, 000
1880	550, 000	1883	900, 000
1881	750, 000	1884	1, 100, 100

KENTUCKY.

In this State are found portions of two coal fields, the great Appalachian system passing across its eastern boundary, and the southeastern extremity of the Illinois field projecting some distance across the western end of the State. Owing to this division of her coal area, Kentucky, in the table showing the area of the coal fields of the United States, does not make a very prominent showing, although her entire coal area is 12,871 square miles, giving her, in a comparison of the States with regard to their total coal area, a place above both Pennsylvania and Ohio. The coal field in the eastern or mountainous portion of the State, in the Appalachian system, has an area of 8,983 square miles, and the western field covers 3,888 square miles of the State's surface. The coal formation of Kentucky is naturally divided by the intercalation of two conspicuous and generally persistent sandstones into three subdivisions, an upper, middle, and lower, the chief coals being found in the last two divisions.

In the eastern field all of the veins which exist in the State are nowhere found, but in the southwestern part of the western field the series is complete, eighteen different beds of coal being recognizable. The united thickness of these eighteen beds is about 43 feet, of which about 13 feet are included in the lower subdivision of the measures, about 24 feet in the middle, and 6 feet in the upper. Of these coals the most reliable both for uniformity of thickness and extent of area are, counting from the lowest, Nos. 1, 9, and 11; No. 12 also often attains a good workable thickness. In the western field No. 1 coal ranges from 4 to 6 feet and is a very reliable bed. No. 9 coal is also persistent and uniform in the western field, averaging 5 feet in thickness, and is probably the best coal of the series; it is excellent for grate and furnace and makes good coke. No. 11 coal attains its greatest thickness in Hopkins county. In the western field cannel coal is found, but only in local deposits.

The eastern Kentucky coal field contains coals even superior to those of the western field in quality and extent, the mineral being found in every county on a line between the Ohio river and the Tennessee State line. Besides its bituminous coal, this field contains one of the largest areas of cannel coal in the country. This coal is from 3 to 4 feet thick and of superior quality.

The coal product of the State has been rapidly increasing of late years and its resources are being very rapidly developed. Railroad facilities are improving, and while last year transportation by river was seriously interfered with by low water, rapid extension of rail-transportation facilities has sufficed to keep the output from being reduced in any considerable quantity. The present Geological Survey is pushing work energetically, and the results of its work will, no doubt, present very fully and accurately the coal resources of the State, and will doubtless shed much light on the correlation of the Coal Measures with those of Pennsylvania, Ohio, and West Virginia. There seems to exist at present no thoroughly reliable information as to the correspondence between the coal systems of Kentucky and the States named.

The report of progress of the Geological Survey announces the discovery in the southeastern part of the State of a very thick coal of great purity, which has been named the Elkhorn coking coal. It has been identified and traced over a large area on the headwaters of the Big Santee, Licking, Kentucky, and Cumberland rivers, where it is found to be from 8 to 9 feet thick, with conditions favorable for cheap mining. The quality of this coal with respect to coking is treated of elsewhere in this report.

Coal production of Kentucky since 1873.

Years.	Long tons.	Years.	Long tons.
1873	300,000	1879	1,000.000
1874	360,000	1880	1,000,000
1875	500,000	1881	1,100,000
1876	650,000	1882	1,300,000
1877	850,000	1883	1,650,000
1878	900,000	1884	1,550,000

MARYLAND.

The Cumberland (George's Creek) coal field, located in Alleghany county, at the western extremity of the State, supplies an important portion of the semi-anthracite coal reaching the seaboard market. The field is about 4 miles wide along the Baltimore and Ohio railroad, where cut by the Savage river and the northern branch of the Potomac, and extends thence for some 30 miles northeast across the State of Pennsylvania, decreasing in breadth until it dies out. This field, so limited in extent, is nevertheless one of the most important coal districts of the country, deriving its position from the great thickness of its coal veins and the purity of the fuel contained therein. The coal, which is known widely as Cumberland or George's Creek coal, is bituminous and of a superior quality. By actual survey it has been ascertained that the field originally contained 17,282 acres of coal, the yield being an average of 5,130 tons to the acre, a rate of production which should exhaust the field about the year 1900. The total thickness of the coal-containing strata in this field is about 1,400 feet, but this thickness does not pervade the entire area. In some places the erosion has been greater, and the chief vein, the "Big" or 14-foot seam, is found only in a few isolated hills. The lowest seam, known as the Parker, at the northern end of the region, lies about 2,500 feet below the horizon of the 14-foot vein; at intervals between these two are found the 6-foot seam, the 3-foot (Savage) seam, the 5-foot 8-inch seam, and the 5-foot 9-inch seam, the latter being about 850 feet below the 14-foot seam. The coal from the smaller veins will hardly come in use to a great extent while that from the greater continues to be mined at so low rate as at present, the 14-foot seam in particular overshadowing the others. This seam is not with perfect accuracy called the 14-foot seam, its real thickness being from 8½ to 12 feet, and is often not worked to its full extent, the roof being insecure. Towards the northeast it becomes thinner and poorer, owing to a gradual increasing intermixture of slate.

The facilities which this region has for transporting its coal to market have largely enhanced its commercial importance. The Baltimore and Ohio railroad began carrying the coal in 1842, the Chesapeake and Ohio canal in 1850, and the Pennsylvania State Line branch in 1872. The George's Creek and Cumberland railroad was completed in December, 1880. The total business since the beginning, in 1842, to the end of 1884, foots up 46,918,604 tons, divided as below:

Carried by—	Long tons.
Baltimore and Ohio railroad	30,301,394
Chesapeake and Ohio canal	14,196,489
Pennsylvania State Line branch	2,420,721

Within the past ten years business has fluctuated as below:

Maryland coal shipments since 1873.

Years.	Baltimore and Ohio.	Chesapeake and Ohio.	Pennsylvania State Line.	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
1873	1,780,710	778,802	114,589	2,674,101
1874	1,576,160	767,064	67,671	2,410,895
1875	1,302,237	879,838	160,698	2,342,773
1876	1,070,775	632,440	131,866	1,835,081
1877	818,450	584,996	170,884	1,574,330
1878	924,254	609,204	145,864	1,679,322
1879	1,075,198	501,247	154,264	1,730,709
1880	1,319,589	603,125	213,446	2,136,160
1881	1,478,502	504,818	278,598	2,261,918
1882	1,085,249	269,782	185,435	1,540,466
1883	1,434,766	680,119	419,288	2,544,173
1884	2,233,928	344,954	356,097	2,934,979

MICHIGAN.

The Coal Measures of Michigan lie in an isolated basin having no connection with the coal of any other State. They are supposed to occupy an area comprising about one-fifth of the central portion of the lower peninsula. The seams of coal are interstratified with beds of shale, beds of coarse, friable sandstone, and clay. The entire formation has an estimated maximum thickness of about 300 feet.

The extent of the coal field is embraced in a circle with a radius of 50 miles, having its center southeast of the village of Saint Louis, in Gratiot county, and its southern boundary passing a few miles south of the city of Jackson. Over the greater portion of this wide field indications of coal have been found, and in many localities some incipient mining work has been done. But a limited amount of systematic exploring has been prosecuted, and the coal seams which have been reached vary from a few inches to a maximum of 4 feet in thickness. The rock beds in lower Michigan have but few exposures; everywhere they are deeply buried by the overlying drift, so that actual boring is required to determine whatever of mineral value may lie beneath the surface in any particular locality. This operation involves considerable trouble and expenditure, and, unless for a specific object, is seldom resorted to. While the coal deposits probably exist over a wide field in Michigan, it by no means follows that the beds are continuous, and that coal may be everywhere found in workable quantity. The basins in which the coal was originally laid down, unprotected by later deposits, have suffered from exposure to the forces of nature during the long geological periods that have intervened. Probably the greater portion of the coal originally deposited in this State during the epoch of the coal formation was subsequently worn away and destroyed by the moving glaciers of the Drift period. The soft, yielding rock deposits of lower Michigan were eroded and swept away by the great rivers of ice that moved over them, to be again buried and hidden beneath the accumulated drift and débris furnished by these glacier masses, and by subsequent geological changes.

The consequent absence of precipices and ledges renders it difficult to study the strata and formations of the State. Enough has been done, however, to prove that in this State there are deposits of coal of necessarily limited extent. So far as is known there is but a single workable seam, and this has only a maximum thickness of 4 feet, with an average of from 2½ to 3 feet. At present there are about five mines in operation.

The following table shows the production of coal in Michigan since 1877; the amount produced previous to 1877 is estimated to be 350,000 tons.

Years.	Long tons.	Years.	Long tons.
1877	69,197	1881	132,130
1878	77,715	1882	130,000
1879	82,015	1883	155,000
1880	130,053	1884	135,000

MISSOURI.

A line drawn from the junction of the Des Moines river with the Mississippi to the southwest corner of the State will have northwest of it nearly all the coal territory of Missouri. An arm of this territory, however, follows the course of the Missouri river east for a short distance, and coal is also found in the vicinity of Saint Louis. The total coal area of the State is about 23,100 miles. The Coal Measures are divided into three parts, as in Iowa—the Upper or Barren Measures, which are exposed over an extent of 8,406 square miles; the Middle, over an extent of 2,000 square miles; and the Lower, over an extent of 12,420 square miles. The aggregate thickness of the upper division is 137 feet, including about 4 feet of coal in two seams of 1 foot each and a few streaks; the middle division is 324 feet thick, with 7 feet of coal, including two workable seams of 21 and 24 inches, and a third of 1 foot worked under favorable circumstances, besides six seams of extreme thinness; the lower division is from 250 to 350 feet, embracing five workable beds varying from 1½ to 4½ feet in thickness, and thin seams between 6 and 11 inches, besides unimportant streaks, in all 13 feet 6 inches. The total thickness is therefore nearly 1,900 feet of Coal Measures and 26 feet 6 inches of coal. The upper division is usually called the Barren Measures. In twenty-four counties coal mines are operated in good veins of workable thickness; in some other counties adjoining these there are coal beds worked with some profit, but they are not so thick and cannot be mined so economically. The mines in Bates and Vernon counties are being rapidly developed. The Bates County district has ample railroad facilities, being traversed by four different lines, and is rapidly growing in importance, producing 600,000 tons last year. Extensive prospecting has developed large beds of fine bituminous coal at depths of 20, 40, and 80 feet, the upper bed being 5½, the middle 6, and the lower 7½ feet thick. The following analysis of Rich Hill, Bates county, coal is presented:

	Per cent.
Moisture	6.50
Volatile matter	36.87
Fixed carbon	52.99
Ash	3.63
	100.00
Sulphur	2.69

The production of coal has been as follows:

Production of coal in Missouri since 1873.

Years.	Long tons.	Years.	Long tons.
1873	700,000	1879	900,000
1874	714,000	1880	1,500,000
1875	750,000	1881	1,750,000
1876	900,000	1882	2,000,000
1877	900,000	1883	2,250,000
1878	900,000	1884	2,500,000

MONTANA.

A large portion of the area of Montana is known to be underlaid by coal, but the explored fields are comparatively limited in extent. While some authorities have estimated that the coal area of the Territory is 60,000 square miles, it is certain that this has been much overestimated. The known and examined coal fields are the Bozeman, 5 square miles; Gardiner, 3 square miles; Rock Creek, 15 square miles; Sand Coulee, 50 square miles; Judith, 24 square miles; Bull Mountain, 60 square miles; and several square miles in the Swimming Woman field. Besides these, there is the vast area bordering on both sides of the Missouri river, extending down to and far below the Yellowstone, and reaching from the eastern boundary of the Territory to the Musselshell river. This eastern field occupies over 25,000 square miles, and at almost every point in it the characteristic lignites can readily be found. Along the line of the Yellowstone, at stations on the Northern Pacific railway, coal mines have been opened from Glendive to Sanders. In the present unsurveyed state of the larger portion of the Territory it is impossible to correctly estimate the coal area, but it seems assured that at least 25,000 square miles of the Territory are coal bearing. The characteristic coal is a rather inferior lignite, but in the Judith, Bozeman, Sand Coulee, Gardiner, and Rock Creek fields the coal is bituminous in character and makes a fair coke. The principal development of the coal of Montana has been made by the Northern Pacific Coal Company, which supplies the fuel of the Northern Pacific railway.

The most important and best developed field yet opened is the Bozeman, which lies along the line of the Northern Pacific railway between Livingstone and Bozeman. The vein here opened is from 3½ to 4 feet in width, and dips at an average 45°, so that the width of the field available for mining does not exceed 2,000 feet. The outcrop extends 11 miles in length. The coal is hard and solid, with bright black color and brown-black streak. It breaks in good square lumps, and also, in other portions of the vein, into friable masses. Both varieties coke well, although coke made from the friable portion seems to be the best. Its character is so good that it is now used exclusively for fuel on the Northern Pacific railway from Glendive, Montana, to Sprague, Washington.

Its composition is indicated by the following analyses:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	3.0	7.0
Volatile matter	41.5	34.5
Fixed carbon	43.5	50.5
Ash	12.0	8.0
	100.0	100.0

The production of coal here began in January, 1883, when 20 tons of coal were mined. During the first six months of 1883, 879 tons were mined, and during the last half of the year 9,580 tons, a total of 10,489 tons. During the first six months of 1884 the production was 20,814 tons.

The Gardiner coal field lies along the upper Yellowstone, in Gallatin county, and is of limited extent. There are here four seams of coal, only one of which is workable. The area of workable coal does not exceed 3 square miles. The coal makes a fair coke. Its composition is:

	Per cent.
Water	1.140
Volatile matter	30.486
Fixed carbon	62.332
Ash	6.033
Sulphur	.009
	100.000

The vein has been opened by Horr Brothers, of Gardiner, who began work in June, 1833. Only four men were employed during 1883, and the product was 485 tons.

Another coal field which promises to be of great importance is the Rock Creek field, on the Crow Indian reservation. The coal field is as yet untouched, but the vein crops out on Rock creek, about 35 miles south of Stillwater, on the Northern Pacific railroad. Some seven seams occur here, and the total thickness of coal exposed is over 40 feet. The thickest single seam is nearly 4 feet. The coal is a good bituminous coking coal, and from the position of the field, the slight dip, good location, and superior quality of the coal, this promises to be one of the best in the Territory. There seems to be some reason to believe that this coal field is the continuation of the Bozeman coal, as similar veins are said to crop out at points farther west in the Crow reservation. The area of the field is about 15 square miles.

The upper Missouri coal field occurs in Choteau and Meagher counties, on both sides of the Missouri river, near Fort Benton. The coal here occurs in rocks of the Dakota formation, and the principal outcrops are on the Sand Coulee and Deep creek and in the neighborhood of Great Falls. The vein is from 4 to 8 feet in width and dips at a slight angle. The coal is of the bituminous variety, is generally non-coking, and is valuable for many uses. The Great Falls Coal Company has opened the vein on its property, comprising 80 acres of land. The mine is located on Deep creek or Smith river, about 55 miles from Fort Benton. The width of the vein worked is 7 feet, and it is developed by a tunnel 160 feet long. The vein has not been worked steadily, nor has any coal been sold except 70 tons hauled to Fort Benton, where it sold readily. The distance and want of cheap transportation have precluded any continuous working of the mine. The coal is of excellent quality, burning freely and leaving but little ash, and cokes well. The vein is free from bone and slate and has a sandstone roof. It is easily worked. Near Anaconda a vein of coal has been opened by Mr. F. A. Barrett, but exploration has not yet extended far enough to determine the width of the vein or the extent of the field. A rough preliminary analysis showed:

	Per cent.
Volatile matter and water	45.09
Fixed carbon	45.77
Ash (reddish yellow)	7.37
Sulphur	1.77
	100.00

The Bull Mountain coal field is about 30 miles north of Billings, and lies between the Yellowstone and Musselshell rivers. The coal occurs in the Laramie formation, and is a lignite of a jet-black color and brown streak. The vein is what is known as the Mammoth, and is from 12 to

14 feet thick, although it is frequently separated by partings into two or three seams. Where separated, the smallest seam is 4 feet wide and the widest 6 feet, and generally aggregates a little greater width than where the vein is solid. The coal has a jointed structure and comes down in large blocks. It is much better than the lignites found further east, but carries much sulphur, the cleavage and bedding planes containing considerable quantities of iron pyrites. The coal has not yet been mined to any extent, but the well-defined outcrop around the entire field affords data for a very close approximation of the amount of coal available for mining. The area of the field is about 60 square miles, and it contains about 400,000,000 tons of available coal. Most of the outcrop is located, and a large portion of the field is controlled by the Northern Pacific Coal Company.

The Judith coal field is situated on both sides of the Judith river, nearly north of the Bozeman field. The explored area of the field is about 12 square miles in extent. The coal occurs in the Dakota rocks and in two veins, one 2 feet and the other from 4 to 6 feet in width. The coal is bituminous, but, so far as explorations have gone, does not coke. The field is of large extent and the veins easily worked, but there has been no development.

Besides these fields described in western and central Montana, coal is known to occur in various other localities, but lack of verification renders the statements too valueless to be quoted.

The eastern coal field is of great extent, but has not been opened except at various points along the line of the Northern Pacific railway, where coal has been mined for quite a number of years, notably at the Lignite mines at Lignite.

The following figures give the production of the Lignite and Bozeman mines for 1884:

Production of coal at the Lignite and Bozeman mines, in Montana, for 1884.

	Lignite mine.	Bozeman mine.
	Short tons.	*Short tons.*
January 1 to September 1 (actual output)	12, 221	25, 558
September 1 to January 1 (estimated)	4, 000	12, 000
Total	16, 221	37, 558

NEBRASKA.

The southwestern corner of Nebraska is covered by a portion of the Missouri coal field, the area being 3,600 square miles. The outcrops belong entirely to the upper of the three divisions of Iowa and Missouri, and the general opinion seems to be that no good workable beds of coal are likely to be found, at least near the surface. Beds of the thickness of 6, 11, 15, and 22 inches are reported from different counties. The coal is usually inferior, but may be used in the neighborhood to some advantage in the absence of all other fuel.

A test well was recently bored by the citizens of Brownsville, Nemaha county, which brought to light some interesting information. The boring was begun at an elevation of 919 feet above sea level, and was carried to a depth of 1,000 feet. The drill penetrated the Lower Coal Measures, but did not pass through them. These measures are those which are productive in Iowa and the States farther east, and it might be expected that coal would be found in them. The only seam found in these measures, however, was one of bituminous coal of fair quality, 30 inches in thickness, at a depth of 820 feet. Above this 30-inch seam three others were found, of 8, 14, and 10 inches in thickness, respectively, and all evidently belonging to the Upper Measures. It seems questionable whether the 30-inch vein will ever prove of practical value, but the nature of the country and the distance from other coal supply will go far towards inducing attempts to utilize it.

NEW MEXICO

In New Mexico coal is found in Colfax, Sante Fé, Rio Arriba, Socorro, Bernalillo, Valencia, and Doña Ana counties, in beds from 1 to 14 feet in thickness. The New Mexican coals range through all varieties from brown coal to anthracite. The most important fields yet opened are those in Colfax county at Raton, which embrace an area of about 600,000 acres, the product being a lignite which varies greatly in quality. The following analyses were made from specimens taken near the surface:

	Top of vein.	Middle.	Bottom.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	2.00	3.10	2.60
Volatile matter	37.10	35.00	34.30
Fixed carbon	51.60	51.50	47.50
Ash	9.30	10.40	15.60
	100.00	100.00	100.00

The mines are from 4 to 6 miles from Raton, and the principal ones are now operated by the Raton Coal and Coking Company, for the benefit of the Atchison, Topeka and Santa Fé railroad. The veins here vary in width from 3 feet in the Blossburg mine to 8½ feet in the Gardner mine. In the Seely mine the coal bed is from 5½ to 6 feet in thickness, and this bed is now largely worked.

The Savage mine, 4 miles north of Raton, opens another bed of coal about 3½ feet thick. The coal here is variable in quality, but generally better than that from other mines near. The mine is idle at present. The Raton coal contains small quantities of sulphur and yields a white ash. The mines here came into the possession of the Atchison, Topeka and Santa Fé Railroad in February, 1881, and during the remainder of the year produced 21,000 tons of coal. In 1882 the output was 91,798 tons, and in 1883, 117,977 tons. Large numbers of coal beds are found in Colfax county, their number being estimated to be about thirty-five, some of which are from 7 to 8 feet in thickness; but their remoteness from the railway renders them without value for the present.

The anthracite and bituminous fields of Santa Fé county cover an area of at least 15,000 acres, a considerable proportion of which is underlaid by four distinct veins of anthracite coal, varying from 2 to 4 feet in width. The coal beds are found between the Rio Galisteo and the Rio Santa Fé, and are about 25 miles southwest of Santa Fé, and not very far from Cerillos station, on the Atchison, Topeka and Santa Fé railroad. They are known as the Los Cerillos beds. The coal is hard, dense, and of brilliant luster, and is said to be, "so far as its application for all practical purposes is concerned, fully equal to the best Pennsylvania anthracite." Its composition is shown by the following analysis:

	Per cent.
Water	2.90
Volatile matter	3.18
Fixed carbon	88.71
Ash	5.21
	100.00

The vein now being worked is the next to the lowest, is 3 feet in width, and from it about 500 tons of good coal were taken in 1882 and shipped to Santa Fé, Albuquerque, and Las Vegas.

About 2 miles west from the anthracite vein now being worked are the bituminous coal mines. Here seventeen veins of coal are exposed, the one on which work is prosecuted being about 4½ feet in width. The coal is remarkably free burning, and about 10,000 tons have been mined to January 1, 1884.

The coal field of Rio Arriba county is opened at Monero, and is an extension of the La Plata County (Colorado) deposit. The veins here are very wide, and have been developed to some extent since the completion of the Durango branch of the Denver and Rio Grande railroad, furnishing the principal supply of fuel for that branch. The coal is in every respect similar to that from the Peacock mine at Durango, and cokes satisfactorily. In 1882 some 12,000 tons were produced.

In Bernalillo county brown coal is extremely abundant, the known area comprising almost the entire western portion of the county. The principal developments are at Gallup and Defiance, and the mines are owned by the Atlantic and Pacific Railroad Company, the fuel supply for the road coming entirely from this locality. In the Tijeras cañon one vein 9 feet thick is exposed, while along the cañons of the upper Rio Puerco veins of brown coal from 4 to 8 feet in thickness are everywhere exposed. The distance of these beds from a market has prevented their development, but the Atlantic and Pacific Railroad Company is now rapidly opening them up. The product of the mines at Gallup from March 20 to December 31, 1882, was 33,373 tons, of which 30,705 tons were used by the railroad and 2,668 tons were shipped for commercial use. The average number of men employed at Gallup is 220.

Near Silver City, Grant county, there is a bed of moderate extent which produces a massive, compact, very hard, and non-intumescent coal of the semi-anthracite variety. Its composition is:

	Per cent.
Water	2.13
Volatile matter	4.86
Fixed carbon	86.56
Ash	6.45
	100.00

It has not yet been developed to any extent.

The coal area in the vicinity of San Antonio, Socorro county, is of considerable extent, but has not yet been fully explored. The field now being worked embraces about 960 acres, and others of unknown value and extent are known to exist a little further north. The mines here are operated by the San Pedro Coal and Coking Company, for the Atchison, Topeka and Santa Fé railway. The coal vein is 6 feet thick, and the product is an excellent coking coal, which contains less than 5 per cent. of ash. The intention of the company is to convert the entire output into coke. The coke is used by the Billings smelter at Socorro, and is also shipped largely to other New Mexican points and to Arizona and Mexico. In 1882 the product of coal amounted to 16,321 tons, and in 1883 to 37,966 tons.

The New Mexican coals compare favorably with those found further north, and only a comparatively small proportion of the Territory is known to be coal-bearing. With further and more thorough exploration other and good beds will probably be found.

The product of the Territory was as follows:

Coal production of New Mexico in 1882, 1883, *and* 1884.

Localities.	1882.	1883.	1884. (*a*)
	Short tons.	*Short tons.*	*Short tons.*
Raton district	91,798	112,089	102,513
Gallup district	33,373	42,000	62,802
Monero	12,000	17,240	11,203
Los Cerillos	3,600	3,000	3,000
San Antonio	16,321	37,018	41,039
Total	157,092	211,347	220,557

a The output for December is estimated.

The capacity of the mines at Raton is stated to be 500 tons daily, of those at Monero 125, of those at San Antonio about 250, and of the mines at Gallup about 350. The Los Cerillos field is yet practically undeveloped. About 600 men are employed in the mines, and about 93 per cent. of their product is consumed by the railways.

Placing the value of these coals at $3 per ton, the value of the product of the Territory during the past three years would be:

Years.	Value.
1882	$471,276
1883	634,041
1884	661,671

NORTH CAROLINA.

It has long been known that there are large deposits of good coal in Stokes county, but owing to lack of transportation facilities the beds have never been mined to any extent, except during the war, when the coal produced acquired a high reputation. The coal is semi-bituminous. The surface indications commence about 4 miles west of Walnut Grove and extend in an easterly direction down the Town fork and the Dan river for a distance of 30 miles. Near Walnut Grove the outcropping shows fourteen beds at a distance of from 30 to 50 feet apart, the dip being about 45°. One vein contains coal very much resembling anthracite. There is some sulphur in the surface vein, but it cokes well. There have been a few small shafts sunk near Stokesburg, but none deeper than 15 feet, one of them striking a solid vein of coal at this depth 6 feet thick. Some of the veins contain shale partings, but with these often show from 2 to 4 feet of clear coal. Two analyses by Dr. Genth of samples of different seams gave respectively 75.96 and 76.56 per cent. of fixed carbon and 11.44 and 13.56 per cent. of ash, the volatile matter being about 12 per cent. in each.

OHIO.

The Coal Measures of Ohio are a part of the Appalachian coal field, the northwestern prolongation of this great field underlying the eastern and southeastern portion of the State. Speaking comparatively, over one-fourth of the State is underlaid with coal-bearing strata, the area so occupied being estimated at from 10,000 to 12,000 square miles. Ohio, therefore, has the third place as to size of coal field among the eight States included in the Appalachian system. According to the nomenclature which most generally obtains in Pennsylvania as to the stratigraphical order of the several veins of coal—that of Prof. H. D. Rogers—the formations in which coal is found in the Ohio are four—the Seral (Pottsville) Conglomerate, the Lower Coal Measures, the Lower Barren Measures and the Upper Coal Measures. There is, however, some dissent to this classification of the Coal Measures of western Pennsylvania and Ohio as to the first two subdivisions. Considering the strata of the territory named, the division into Conglomerate and Lower Measures appears decidedly arbitrary, and the classification seems only to have been made through the supposed establishment of equivalency between the varied seams of these measures in western Pennsylvania and the great Pottsville Conglomerate of eastern Pennsylvania. In point of fact, there is in Ohio no more marked separation between the highest coal seam of the Conglomerate series and the lowest of the Productive Measures than can be found between any two coals of the latter division; and, with the sanction of Professors Newberry and Lesley, while accepting the identification referred to as a matter of geological history, the subdivisions may be considered as three—the Lower Coal, the Lower Barren, and the Upper Coal Measures.

The Lower Coal Measures are most widely distributed in Ohio. An imaginary line drawn from the Pennsylvania boundary in Trumbull county northwestwardly to near Lake Erie, and thence southwest by south to the Ohio river in Scioto county, will roughly indicate the northern and western boundaries of these measures, the entire portion of the State between the line and the Ohio river, the eastern and southern boundary of the State, being underlaid with coal-bearing strata. The Lower Measures have an average thickness of about 500 feet. Twelve seams of coal occur in these measures, all of which have, with more or less certainty, been identified with the seams of the corresponding measures in Pennsylvania, the nomenclature of which State will be used in discussing them. The most important veins are the Sharon, the Brookville, the Lower Kittanning, the Middle Kittanning, and the Upper Freeport seams.

The Sharon coal, occurring in the so-called Conglomerate, is mined in the seven counties which constitute the northeastern corner of the coal field of Ohio, and also seems to be the coal which is mined in Jackson county. This seam has long been considered one of the most important veins in the State, and has been very largely used as a blast-furnace fuel. It is unfortunately very uncertain as to quantity, ranging sometimes from 6 to 7 feet thick, and frequently thinning out and entirely disappearing; and also as to purity, many gradations in quality being found, often in close proximity. The Sharon seam has its best development in the Mahoning valley, where it receives the name of block coal, being very compact, and, when mined with skill, making very little slack. It is also known here as the Brier Hill coal. The Mahoning Valley deposits are being rapidly exhausted, and, owing to competition, no longer command as high a price as formerly. The following is an analysis of this coal:

	Per cent.
Moisture	3.60
Volatile combustible matter	32.58
Fixed carbon	62.66
Ash	1.16
	100.00
Sulphur	.85
Specific gravity	1.284

In Summit, Stark, Medina, and Wayne counties, collectively called the Massillon district, the Sharon coal is largely mined, and has here less of the block character and is more bituminous. It analyzes as follows:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	6.95	4.10
Volatile combustible matter	32.38	32.90
Fixed carbon	57.49	61.40
Ash	3.18	1.60
	100.00	100.00
Sulphur	.88	1.07
Specific gravity	1.247	1.250

In Jackson county this seam is mined largely for iron-smelting purposes, and the coal resembles the Mahoning Valley block coal. Analyses show a coal low in sulphur and high in carbon, but with considerable moisture.

The Brookville seam is quite widely spread throughout the State, and is mined, though principally for local consumption, in some seven or eight counties, receiving in Stark county, where it is at its best, the title of gray limestone coal, from the thick stratum of that nature which overlies it. The following analysis shows its composition:

	Per cent.
Moisture	7.00
Volatile combustible matter	30.80
Fixed carbon	59.50
Ash	2.70
	100.00
Sulphur	.65

The Lower Kittanning vein is one of the most important seams of the State. It is found in great purity as the Leetonia coal in Columbiana county, where it is coked for blast-furnace use. It thins somewhat in Stark county, but regains its volume and is mined at Mineral Point, Tuscarawas county, in Muskingum and Perry counties, and in large quantities in Lawrence county. It is, however, somewhat overshadowed by the Middle Kittanning coal, which lies from 20 to 50 feet above it, the continuance of the two veins being very steady and persistent.

The Middle Kittanning is doubtless the most important coal seam in the State. Although traceable from Columbiana county westward and southward, it does not attain its greatest importance until in the vicinity of New Lexington, Perry county. From this place southward it acquires much greater volume, and becomes the "Great vein" of the Hocking valley, being also widely known as Straitsville and Nelsonville coal. In Perry county a change in the composition of the coal also occurs. Hitherto it is a moderately cementing, red-ash coal; but in the neighborhood of New Lexington, simultaneously with its increase in volume, it changes to a white-ash, open-burning coal. These latter characteristics it retains throughout its entire southward extension, although varying somewhat in volume. The following figures show the result obtained by averaging the analyses of ten specimens of coal obtained from as many different mines in the "Great vein" of the Hocking valley:

	Per cent.
Moisture	5.98
Volatile combustible matter	36.48
Fixed carbon	52.41
Ash	5.13
	100.00
Sulphur	1.09

The following are the two analyses of the ten which present respectively the best and the poorest showing:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	6.62	5.38
Volatile combustible matter	36.40	37.58
Fixed carbon	54.17	51.21
Ash	2.81	5.83
	100.00	100.00
Sulphur	.51	1.94

These figures show that the coal of the "Great vein" is remarkably steady in composition. It is highly esteemed as a blast-furnace and steam coal, and may safely be said to be second in value to the Mahoning Valley block coal alone.

The Upper Freeport seam stands second in importance among the coal seams of the State. It is the basis of three well-developed and important fields—Salineville, Sherrodsville, and Cambridge. It is mined to a considerable extent in Muskingum, Perry, and Athens counties, and is as yet undeveloped in what appears to be one of its most promising basins, the Waterloo district of Gallia and Lawrence counties. It is a moderately coking coal, sometimes high in sulphur, but in its best phases highly valued as a steam coal. The composition of the "Big vein" coal at Salineville, Columbiana county, is shown below:

	Per cent.
Moisture	2.32
Volatile matter	39.08
Fixed carbon	52.78
Ash	5.82
	100.00
Sulphur	2.88

The strata lying between the massive Mahoning sandstone, which overlies the Upper Freeport coal, and the great Pittsburgh coal seam have received the name of the Lower Barren Measures. The name is especially apt when applied to the strata as they are disclosed in Ohio. The Lower Barren Measures consist of alternations of sandstone, shale, and limestone, to the thickness of about 400 to 500 feet, intercalated with streaks of coal which but rarely become of workable thickness. In northeastern Ohio these measures retain this character for a long distance westward. The only workable vein of coal in these measures in this division of the State is the Salineville strip vein, in Columbiana county; and even this vein is claimed by Professor Newberry for the Lower Coal Measures. As, however, its place is plainly above the Mahoning sandstone, the accepted foundation of the Lower Barren Measures, it seems rightfully to belong to the latter subdivision. Its composition is shown by the following analysis:

	Per cent.
Moisture	1.70
Volatile combustible matter	34.30
Fixed carbon	59.50
Ash	4.50
	100.00
Sulphur	1.62

In central and southern Ohio, however, the Lower Barren Measures are less barren. Several beds of coal of sufficient size to be worked remuneratively occur, but are comparatively small and very uncertain. In Carroll, Muskingum, and Guernsey counties coal is found in these measures, and in the former county one of the beds is mined in several places, receiving the name of Harlem coal. In Jefferson county two seams of cannel coal are found, but are of poor quality and are local.

The Upper Coal Measures have for their base the well-known Pittsburgh seam, and are chiefly important, from our standpoint, as containing this valuable bed. The Pittsburgh seam exhibits two lines of outcrop in Ohio. Entering the State in Jefferson county, one of these lines passes down the Ohio River valley, and from Steubenville to Bellaire is mined almost continuously, the thickness between these two points varying from 5 to 9 feet, and the quality being generally excellent. The following analyses show the composition of the Pittsburgh seam along the Ohio river, the specimen in No. 1 being from Jefferson county and that in No. 2 from Belmont county:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	1.45	1.00
Volatile combustible matter	36.35	34.20
Fixed carbon	57.95	59.40
Ash	4.25	5.40
	100.00	100.00
Sulphur	2.72	2.63
Specific gravity	1.302	1.290

Below Bellaire the dip is rapid, and the seam passes to a great depth below the level of the Ohio river. Returning to the starting point in Jefferson county, the second line of outcrop passes through the State in a tortuous but generally southwestward direction. The following counties are crossed by this line: Jefferson, Harrison, Belmont. Guernsey, Muskingum, Morgan, Athens, and Meigs. In the last county the line reaches and crosses the Ohio river into West Virginia. In Muskingum county the seam is quite thin, but in Morgan and Athens counties ranges from 5 to 9 feet in thickness, and attains great importance at Pomeroy, Meigs county, on the Ohio river, where it is very largely mined, being widely known by the title of Pomeroy coal. It is very highly esteemed as both a steam and mill coal. The following analyses, though fairly typical, show a considerable variation in the amount of sulphur—No. 1, of a sample from Athens county, exhibiting a very high percentage, while No. 2, from Pomeroy, is very low in this respect:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	2.70	4.10
Volatile combustible matter	35.30	33.90
Fixed carbon	55.05	56.10
Ash	6.95	5.90
	100.00	100.00
Sulphur	5.24	.46
Specific gravity	1.304	1.358

The remaining coal veins of the Upper Coal Measures, some four or five in number, are of little economical importance in Ohio. The first and second seams above the Pittsburgh bed (Nos. 9 and 10 of Newberry) are thin along the Ohio river, but are persistent, and No. 10 thickens toward the west. It seems to be the vein mined at Cumberland, Muskingum county. The next vein, No. 11, is referred by Professor Newberry to the Waynesburg stratum in Pennsylvania, and attains some commercial importance in Belmont county, but is very unreliable.

Strikes.—The miners' strike in the Hocking Valley region which took place in 1884 probably attracted as much if not more attention than any other labor difficulty which occurred during the year. In the spring of 1884 the coal trade was much depressed, with but little prospect of improvement. The miners were receiving 70 cents per ton, but the mines were for the most part idle, working only occasionally when a chance order for coal would be received. From four to ten days' work per month was the average for the district. On April 22 a joint notice was issued by the Columbus and Hocking Coal and Iron Company, owning some sixteen mines and six blast furnaces, and the Ohio Coal Exchange, to the effect that if they were to hold their trade and give their employés work, the price for mining must be reduced to 60 cents per ton. On April 30 the miners met and issued an address to the public, giving their arguments and reasons against the reduction, and asking the Columbus and Hocking Coal and Iron Company—the syndicate, as it was generally known—and the Coal Exchange to withdraw it. On May 1 a general convention of the miners of the district was held, and it was resolved to indefinitely postpone the consideration of the syndicate's proposition. Relations between the miners and operators gradually became somewhat strained, and on June 20 the syndicate and the Coal Exchange formally announced that the price paid for mining was reduced to 60 cents. The mines being idle, the miners could take no action except to persist in stating that they could accept no such reduction. Finally, on July 5 the two corporations issued a notice to the effect that their offer of 60 cents was withdrawn, and on July 12 the miners were paid off and ordered to remove their tools from the mines. Three thousand men were thus thrown out of work.

Then began a series of depredations made by the miners on the property of the corporations. The latter began to import labor to work the mines, and were compelled to guard their new hands by employing a force of detectives and others. These guards were several times attacked by the strikers, and property of the corporations was burned and destroyed, the latter being eventually compelled to ask that the militia be called out. This was done September 2. The militia were stationed at several places throughout the region, and remained in service for a month. Many of the strikers left the valley, and several mines in the district which were paying the price demanded by the miners employed many of them, and these miners contributed liberally of their earnings to the aid of the strikers. Contributions of food and money from other mining districts, from trades unions, and the general public, also came in largely, and commissaries were established throughout the valley, where weekly rations were served out to the strikers. Seldom, if ever, in the history of strikes, has such thorough organization existed on both sides, and such firm determination to succeed. At present the Columbus and Hocking Coal and Iron Company is paying the miners employed in its mines 50 cents a ton, while at most of the other mines 40 cents prevails, many miners who struck last year against the reduction from 70 to 60 cents now working at this price. In the Sunday Creek valley the 40 cent rate also prevails.

Two other strikes of importance took place in Ohio during 1884. One at Dell Roy, in Carroll county, was caused by a proposed reduction of 13 cents in the price of mining, and, after a strong resistance of six months, was ended by the miners accepting the reduction. An interesting outgrowth of this strike, but immediately caused by a reduction of wages in some mines near by, was the organization of certain miners into coal-mining companies. Two were formed, and are now working mines upon leased property. The other strike, occasioned mainly by the reduction in the Hocking valley, took place in the Coalton and Wellston district, in Jackson county, and lasted about a month. It was ended by an amicable agreement.

Comparison with the figures of production given in the first volume of this series will show a slight difference between them and the figures given below. These for the years previous to 1883 are the estimates made by Mr. Andrew Roy, late mine inspector of Ohio, in the absence of exact figures, and for the years 1883 and 1884 are the production as compiled by the present mine inspector. The facilities for collecting statistics of production are now such that the reports of the mine inspector must necessarily be quite accurate.

Production of coal in Ohio.

Years.	Long tons.	Years.	Long tons.
1872	5, 315, 294	1879	6, 000, 000
1873	5, 450, 0[illegible]8	1880	7, 000, 000
1874	3, 267, 585	1881	8, 225, 000
1875	4, 864, 259	1882	9, 450, 000
1876	3, 500, 000	1883	8, 229, 429
1877	5, 250, 000	1884	7, 650, 062
1878	5, 500, 000		

OREGON.

The coal mines in Oregon are mainly located on Coos bay, on the western coast of the State, about 100 miles north of the California boundary and 40 miles north of Cape Blanco. The Coos Bay coal field covers several hundred square miles of territory, stretching from the Umpqua river on the north to points beyond the Coquille river on the south, and extending back from the coast from 15 to 20 miles. The country is covered with a heavy growth of timber. The field can be worked profitably only where the coal is of good quality, favorably situated for cheap mining, and very close to navigable waters. The vein worked at the Southport mine, on Coos bay, is from 4 feet 6 inches to 5 feet thick. The price paid for mining this seam is 87½ cents a cubic yard, the miners being furnished with tools, but boarding themselves

The following analyses are given:

	Coos bay.	Astoria.
	Per cent.	*Per cent.*
Water	20.00	2.56
Volatile matter	32.59	46.29
Fixed carbon	41.98	48.49
Ash	5.34	2.74
	99.91	100.08

PENNSYLVANIA–ANTHRACITE.[a]

Of comparatively insignificant extent, the anthracite coal basins are without doubt the most important, commercially speaking, in the country. The chief fields are four in number, and are contained in

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[a] See also the paper by Dr. H. M. Chance on the technology of anthracite coal mining, this volume.

most part in the counties of Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, and Dauphin. Susquehanna, Wayne, Lebanon, and Sullivan counties also contain small areas, that in the latter being a detached deposit, known as the Loyalsock field, which produces anthracite different in character from that produced in the main fields. The chief fields, with their respective areas, are as follows:

Fields.	Square miles.
Northern field	198
Eastern middle or Lehigh field	37
Western middle field	91
Southern field	142.5
	468.5

It would not be possible to give any detailed description of the various beds as they appear in different parts of the region. The beds themselves have by no means been traced throughout the district, the peculiar position of the strata, the variation in the thickness of the beds, and the inconsistency which has generally prevailed in naming them presenting serious obstacles. The several fields must therefore be treated separately.

Northern field.—The northern field is contained, with the exception of the extreme northeastern end, in the counties of Lackawanna and Luzerne. The northeastern half, drained by the Lackawanna river, is generally known as the Lackawanna basin, and the southwestern half, through which the North branch of the Susquehanna river flows, is known as the Wyoming basin.

The general geological structure of this field is that of a broad synclinal with comparatively low dips. The deepest part of the field is in the southwestern end, where the red-ash coal bed, which is the lowest bed which has been proved here of workable thickness, occurs about 1,100 feet vertically below the surface.

In the vicinity of Carbondale there are 300 feet of Coal Measures, containing six individual coal beds, with an aggregate thickness of 26 feet. At Scranton, farther to the southwest, the Coal Measures are 700 feet thick, and contain eleven coal beds, with an aggregate thickness of 72 feet. In the vicinity of Wilkes-Barre there are 1,000 feet of Coal Measures, containing thirteen coal beds, having an aggregate thickness of 94 feet, and near Nanticoke over 1,000 feet of Coal Measures, with fifteen beds, aggregating 102 feet in thickness. The coal bed thicknesses include, of course, slate and bony coal, which are intercalated with the different coal benches of the individual beds, so that the thickness assigned to the beds does not represent the actual thickness of coal which can be mined and sent to market.

Eastern middle field.—The eastern middle or Lehigh coal field is contained mostly in the southern part of Luzerne and northern part of Carbon counties. The principal basins contained in it are the upper

Lehigh, Black Creek, West Cross Creek, Hazleton, and Beaver Meadow basins. They are narrow and comparatively shallow as compared with the other anthracite basins. The deepest parts of the Black Creek and West Cross Creek basins contain about 500 feet of Coal Measures above the lowest bed, with about 75 feet of coal, divided into eight different beds.

The Hazleton basin contains about 700 feet of strata above the lowest coal bed, and there are about the same number of beds, with an average thickness possibly a little greater than in the former basin. At one point in the Black Creek basin the Mammoth bed is between 60 and 90 feet thick over a large area where the coal bed is worked.

Western middle field.—This is contained in the counties of Schuylkill, Columbia, and Northumberland. The geological structure of this field is somewhat different from that of either the northern or the Lehigh field. Although the outline of the bottom of the Coal Measures is continuous around the entire field, as it is in the northern field, yet it is broken up into a number of independent basins by prominent anticlinals, as in the Lehigh field, but which do not separate the district into isolated areas underlaid by the Coal Measures, as in the Lehigh. The dip of the coal in this field is generally much greater than in the northern field, while it may be considered to be nearly the same as the average dip of the Lehigh field. In the eastern half of this district there is a thickness of about 1,000 feet of Coal Measures over the Buck mountain, which is the lowest bed exploited, and which probably corresponds to the red-ash bed of the northern field. The total average thickness of all the coal beds here is probably about 110 feet, divided into thirteen individual beds. In the vicinity of Shenandoah, the Mammoth bed measures over 100 feet in thickness. In the western half of this field there is a thickness of about 1,600 feet of Coal Measures above the Lower Lykens Valley bed, which may probably here prove workable. There is here an average thickness of about 120 feet of coal, contained in sixteen different beds.

Southern field.—The southern coal field lies in the counties of Carbon, Schuylkill, and Dauphin, with a small area in Lebanon. The eastern portion of the field, between the Lehigh and the Little Schuylkill rivers, is known as the Panther Creek basin, and has always been included in the Lehigh field, from the fact that most of the coal which has been mined from it has been shipped down the Lehigh river. That portion of the field west of the Little Schuylkill river is generally known as the Schuylkill coal field. More recently the same name has been applied to the western middle field, although not half of this latter field lies in Schuylkill county. The bulk of the coal, however, which is mined from it has been shipped through the Schuylkill valley. The deepest basins in the region are contained in this field. In many cases the individual basins are no broader than those of the western middle or eastern middle field; consequently the highest dips are found in the southern field. At Tamaqua, which is on the Little Schuylkill river, near the eastern end of the field, there is a thickness of Coal Measures of 2,300 feet, which contained twenty-one coal beds, with an aggregate thickness of 126 feet, although, as has been stated, one of the beds, the Mammoth, is 114 feet thick a short distance east of Tamaqua. In the vicinity of Pottsville there are about 3,300 feet of Coal Measures, which contain twenty-eight individual beds, with an aggregate average thickness of 154 feet.

Thickness and contents of the measures.—The aggregate thickness assigned to the Coal Measures in the northern field is that determined near the center of the basin, where the strata are frequently nearly horizontal for several hundred feet, so that the thickness of the strata represents the depth of the coal basin. In the other three fields, however, on account of the steepness of the dip of the strata and the sharpness of the bottom of the basins, their depth is much greater than the thickness assigned to the strata. For instance, at Tamaqua, which may be considered a fair illustration, there are 2,300 feet of Coal Measures above the lowest coal bed; this bed, however, in the center of the Tamaqua basin, is 2,800 feet vertically below the surface of the ground.

A number of estimates have been made as to the total contents of the anthracite basins and their probable life. These have been based upon very general, and in many cases questionable, data, so that nothing is certainly known, from a systematic examination of the entire region, as to what the total contents are. Estimates will, however, be made by the State Geological Survey before the completion of the work. They have already been completed for the Panther Creek basin, whose area, as has been already noted, is 12.5 square miles. This basin originally contained 1,032,997,000 long tons. The area which had been exhausted, and was under exploitation at the end of 1882, originally contained 92,189,000 tons. Out of this area there have been taken 54,116,000 tons.

Anthracite analyses.—The following table of analyses of Pennsylvania anthracite has been prepared by Mr. Ashburner:

Analyses of Pennsylvania anthracite.

	Eastern middle field.		Western middle field.				Southern field.		Northern field.
	Wharton bed.	Mammoth bed.	Primrose bed.	Mammoth bed.	Buck Mountain bed.	Seven-foot bed.	Primrose (?) F bed.	Mammoth bed.	Mammoth bed.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Water	3.713	4.119	3.541	3.163	3.042	3.410	3.008	3.087	3.421
Volatile matter	3.080	3.084	3.716	3.717	3.949	3.978	4.125	4.275	4.381
Fixed carbon	86.404	86.379	81.590	81.143	82.662	80.868	87.982	83.813	83.268
Sulphur	.585	.496	.499	.899	.462	.512	.506	.641	.727
Ash	6.218	5.922	10.654	11.078	9.885	11.232	4.379	8.184	8.203
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Specific gravity	1.620	1.617	1.654	1.657	1.667	1.651	1.584	1.631	1.575

Anthracite production.—A number of statistical tables have been prepared by different authorities to show the past production of the anthracite region. Of these the table printed below seems to have the most in its favor. It has been compiled by Prof. P. W. Sheafer for the years 1820 to 1868, inclusive, and since 1868 by Mr. John H. Jones, accountant of the anthracite transporting companies, and has been adopted by Mr. Ashburner for the use of the State Geological Survey. This table does not include the coal sold to the local trade and consumed for fuel at the collieries. This amount in the past has been variously estimated to be from 8 to 10 per cent. of the total tonnage reported as shipped to market. At the present time it would seem to range from 5 to 6½ per cent. in the different parts of the anthracite region. Although the amount of coal burned within the region has increased from year to year, the percentage of the total amount mined which has been so used has unquestionably diminished at the same time.

Shipments of coal from the anthracite fields of Pennsylvania from 1820 to 1884, inclusive, with the amount and percentage of the total shipped from each region.

Years.	Schuylkill region.		Lehigh region.		Wyoming region.		Total.
	Long tons.	*Per ct.*	*Long tons.*	*Per ct.*	*Long tons.*	*Per ct.*	*Long tons.*
1820	....	....	365	....	....	....	365
1821	....	....	1,073	....	....	....	1,073
1822	1,480	39.79	2.240	60.21	....	....	3,720
1823	1,128	16.23	5,823	83.77	....	....	6,951
1824	1,567	14.10	9,541	85.90	....	....	11,108
1825	6,500	18.60	28,393	81.40	....	....	34,893
1826	16,767	34.90	31,280	65.10	....	....	48.047
1827	31,360	49.44	32,074	50.56	....	....	63.434
1828	47.284	61.00	30,232	39.00	....	....	77,516
1829	79,973	71.35	25,110	22.40	7,000	6.25	112,083
1830	89,984	51.50	41,750	23.90	43,000	24.60	174,734
1831	81,854	46.29	40,966	23.17	54,000	30.54	176.820
1832	209,271	57.61	70.000	19.27	84,000	23.12	363,271
1833	252,971	51.87	123 001	25 22	111.777	22.91	487,749
1834	226.692	60.19	106,244	28.21	43,700	11.60	376,636
1835	339,508	60.54	131,250	23.41	90,000	16.05	560,758
1836	432,045	63.16	148,211	21.66	103.861	15.18	684.117
1837	530,152	60.98	223,902	25.75	115,387	13.27	869.441
1838	446,875	60.49	213,615	28.92	78,207	10.59	738,097
1839	475.077	58.05	221,025	27.01	122,300	14.94	818.402
1840	490,596	56.75	225,313	26.07	148,470	17.18	864,379
1841	624,466	65.07	143,037	14 90	192,270	20 03	959.773
1842	583,273	52.62	272.540	24.59	252,599	22.79	1,108.412
1843	710,200	56.21	267,793	21.19	285,605	22.60	1,263 598
1844	887,937	54.45	377,002	23.12	365,911	22 43	1,630.850
1845	1,131,724	56.22	439,453	21.33	451,836	22.45	2,013,013
1846	1,308,500	55 82	517,116	22.07	518.389	22.11	2,344.005
1847	1,665,735	57.79	633,507	21.98	583,067	20.23	2,882,309
1848	1,733,721	56.12	670,321	21.70	685,196	22.18	3,089,238
1849	1,728,500	53.30	781,556	24.10	732,910	22.60	3,242.966
1850	1,840,620	54 80	690,456	20.56	827,823	24.64	3,358,899
1851	2,328.525	52.34	964,224	21.68	1,156,167	25.98	4,448,916
1852	2,636,835	52.81	1,072,136	21.47	1,281.500	25.72	4,993.471
1853	2,665 110	51.30	1,054,3 9	20.29	1,475,732	28.41	5,195.151
1854	3,191,670	53.14	1,207,186	20.13	1,603,478	26.73	6,002,334
1855	3,552,943	53 77	1,284,113	19.43	1,771.511	26.80	6,608,567
1856	3,603,029	52.91	1.351,970	19.52	1,972.581	28 47	6,927.580
1857	3,373.797	50.77	1,318,541	19 84	1.952,603	29.39	6,644.941
1858	3,273.245	47.86	1.380,030	20.18	2,186,094	31.96	6,839 369
1859	3.448,708	44.16	1 628.311	20.86	2,731,236	34.98	7,808.255
1860	3,749.632	44 04	1.821,674	21.40	2,941,817	34.56	8,513.123
1861	3.160,747	39.74	1,738.377	21.85	3,055.140	38.41	7,954.264
1862	3,372,583	42.86	1.351.054	17. 7	3,145.770	39.97	7,869,407
1863	3,911,683	40.90	1,894.713	19.80	3,759,610	39.30	9,566,006
1864	4,161,970	40.89	2,054,669	20.19	3,960,836	38.92	10,177,475
1865	4,356,959	45.14	2,040,913	21.14	3,254,519	33.72	9,652,391
1866	5,787,902	45.56	2,179,364	17.15	4.736,616	37.29	12,703,882
1867	5,161,671	39.74	2,502,054	19.27	5,325,000	40.99	12,988,725
1868	5,330,737	38.62	2,502,582	18.13	5,968,146	43.25	13,801,465

Shipments of coal from the anthracite fields of Pennsylvania, &c.—Continued.

Years.	Schuylkill region.		Lehigh region.		Wyoming region.		Total.
	Long tons.	*Per ct.*	*Long tons.*	*Per ct.*	*Long tons.*	*Per ct.*	*Long tons.*
1869	5,775,138	41.66	1,949,673	14.06	6,141,369	44.28	13,866,180
1870	4,968,157	30.70	3,239,374	20.02	7,974,660	49.28	16,182,191
1871	6,552,772	41.74	2,235,707	14.24	6,911,242	44.02	15,699,721
1872	6,694,890	34.03	3,873,339	19.70	9,101,549	46.27	19,669,778
1873	7,212,601	33.97	3,705,596	17.46	10,309,755	48.57	21,227,952
1874	6,866,877	34.09	3,773,836	18.73	9,504,408	47.18	20,145,121
1875	6,281,712	31.87	2,834,605	14.38	10,596,155	53.75	19,712,472
1876	6,221,934	33.63	3,854,919	20.84	8,424,158	45.53	18,501,011
1877	8,195,042	39.35	4,332,760	20.80	8,300,377	39.85	20,828,179
1878	6,282,226	35.68	3,237,449	18.40	8,085,587	45.92	17,605,262
1879	8,960,829	34.28	4,595,567	17.58	12,586,293	48.14	26,142,089
1880	7,554,742	32.23	4,463,221	19.05	11,419,279	48.72	23,437,242
1881	9,253,958	32.46	5,294,676	18.58	13,951,383	48.90	28,500,017
1882	9,459,288	32.48	5,689,437	19.54	13,971,371	47.98	29,120,096
1883	10,074,726	31.68	6,113,809	19.23	15,604,492	49.08	31,793,027
1884	9,478,314	30.86	5,562,266	18.11	15,677,713	51.04	30,718,293
Total	202,876,712	38.26	100,596,643	18.97	226,738,455	42.70	530,211,810

The Schuylkill region includes the western middle coal field and that portion of the southern coal field west of Tamaqua. The Lehigh region includes the eastern middle coal field and that portion of the southern coal field east of Tamaqua, known as the Panther Creek basin. The Wyoming region includes the Wyoming and Lackawanna basins, which together form the northern coal field.

Shipments of coal from the anthracite coal fields of Pennsylvania, arranged in periods of ten years, from 1820 to 1884, inclusive.

Years.	Schuylkill region.	Lehigh region.	Wyoming region.	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
1820 to 1830	276,043	207,881	50,000	533,924
1831 to 1840	3,485,041	1,503,527	951,702	5,940,270
1841 to 1850	12,214,676	4,782,781	4,895,606	21,893,063
1851 to 1860	31,823,494	13,082,494	19,075,719	63,981,707
1861 to 1870	45,987,547	21,452,773	47,321,666	114,761,986
1871 to 1880	70,823,625	36,906,999	95,238,803	202,969,427
1881 to 1884	38,266,286	22,660,188	59,264,959	120,131,433
Total	202,876,712	100,596,643	226,738,455	530,211,810

Anthracite coal tonnage of the different transportation companies for the years named.

[Compiled upon the basis of distribution established by the Anthracite Board of Control for 1878, by Mr. John H. Jones.]

Companies.	1870.	1871.	1872.	1873.	1874.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Philadelphia and Reading Railroad Company	4,169,707	5,330,863	5,645,103	5,868,848	5,568,601
Lehigh Valley Railroad Company	3,608,587	2,880,263	3,850,118	4,121,734	3,989,821
Central Railroad Company of New Jersey	1,606,469	1,985,550	2,253,614	2,698,119	2,706,007
Delaware, Lackawanna, and Western Railroad Company	2,117,612	1,730,242	2,520,330	2,952,941	2,353,539
Delaware and Hudson Canal Company	2,318,073	1,955,737	2,882,479	2,732,267	2,290,791
Pennsylvania Railroad Company	1,225,733	912,835	1,168,084	1,519,711	1,642,474
Pennsylvania Coal Company	1,136,010	848,635	1,266,762	1,297,604	1,396,326
New York, Lake Erie, and Western Railroad	....	55,596	83,288	36,728	197,562
Total	16,182,191	15,699,721	19,669,778	21,227,952	20,145,121

Anthracite coal tonnage of the different transportation companies, &c.—Continued.

Companies.	1875.	1876.	1877.	1878.	1879.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Philadelphia and Reading Railroad Company	4,782,311	4,931,754	6.842,105	5,112,219	7,442,617
Lehigh Valley Railroad Company	3,285,225	3,985,351	4,447,881	3,403,318	4,405,958
Central Railroad Company of New Jersey	2,465,902	2.778,096	2,837,500	2,264,979	3,825,553
Delaware, Lackawanna, and Western Railroad Company	2,833,670	1,998,654	2,089,523	2,180,673	3,867,405
Delaware and Hudson Canal Company	2,843,229	1,809,190	1,787,470	2,046,235	3,014,117
Pennsylvania Railroad Company	1,772,719	1,623,335	1,530,594	1,362,674	1,682,106
Pennsylvania Coal Company	1,426,377	1,143,922	1,118,011	957,032	1,427,150
New York, Lake Erie, and Western Railroad	303,039	230,709	175,095	278,132	477,783
Total	19,712,472	18,501,011	20,828,179	17,605,262	26,142,689

Companies.	1880.	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Philadelphia and Reading Railroad Company	5,933,923	6,940,283	7,000,113	10.487,003	11,163,920
Lehigh Valley Railroad Company	4,394,533	5,721,870	5,933,740	6,271,773	5,935,254
Central Railroad Company of New Jersey	3,470,141	4,085,424	4,211,052	[a]1,745,399	....
Delaware, Lackawanna, and Western Railroad Company	3,550,348	4,388,970	4,638,717	5,079,123	5,204,362
Delaware and Hudson Canal Company	2,674.705	3.211,496	3,203,168	3.512,971	3,362,680
Pennsylvania Railroad Company	1,864,032	2,211.363	2,332,974	2,773,419	3,169.287
Pennsylvania Coal Company	1,158,466	1,475,380	1,460,821	1.541,145	1,397,946
New York, Lake Erie, and Western Railroad	411,094	465,230	330,511	382,194	484,844
Total	23,437,242	28,500,016	29,120,096	31,793,027	30,718,293

[a] To June 1, 1883; the road was then leased to the Philadelphia and Reading Railroad Company, which after that date is credited with the tonnage of both its own and the Central roads.

The amount of coal which still remains to be mined has been variously estimated, but all the estimates have been based upon insufficient facts, and until the completion of the State survey but little can be certainly known. Mr. Ashburner has estimated that the region originally contained about 25,000,000,000 tons, which is between the extreme estimates which have been made, and is probably nearer the truth than any other.

In the preceding statistics the production of the Loyalsock basin, in Sullivan county, has not been included. The following table gives the figures in regard to this field:

Production of the Loyalsock field, Sullivan county.

Years.	Long tons.	Years.	Long tons.
1871	23,122	1879	50.000
1872	51,527	1880	65,000
1873	32,058	1881	70,000
1874	36,268	1882	70,000
1875	16.522	1883	80.000
1876	30,000	1884	85.393
1877	23,000		
1878	37,000	Total	669,890

Ownership.—On the anthracite coal fields of Pennsylvania the land is owned by large corporations, whose respective interests are shown in the following table:

Ownership of anthracite coal lands.

Companies.	Schuylkill.		Lehigh.		Wyoming.	
	Acres.	*Per cent.*	*Acres.*	*Per cent.*	*Acres.*	*Per cent.*
Lehigh Valley			18, 036	24	6, 934	4
Lehigh and Wilkes-Barre	7, 600	8	7, 000	8	7, 400	5
Delaware and Hudson					20, 042	12
Delaware, Lackawanna, and Western					3 500	3
Pennsylvania Coal Company					10, 000	6
Philadelphia and Reading Coal and Iron Company	65, 306	70	23, 250	32		
Philadelphia Railroad Company	6, 000	6	9, 000	9	5, 823	6
Girard estate			6, 000	8		
Gilbert & Co			1, 373	2		
Alliance Coal Mining Company	3, 172	3				
All others	11, 362	13	15, 981	17	73, 021	64
Total	93, 410	100	80, 640	100	126, 720	100

Routes and markets.—The several routes to market and their respective lengths are shown in the following table:

Anthracite shipment routes.

From—	By—	Miles.
Pottsville to New York	Canal	226
Pottsville to Philadelphia	do	106
Pottsville to Philadelphia	Rail	93
Mauch Chunk to New York	Lehigh canal	172
Mauch Chunk to New York	Rail	126
Mauch Chunk to Philadelphia	Canal	1[illegible]4
Mauch Chunk to Philadelphia	Rail	89
Carbondale to New York	Rail and canal	208
Scranton to New York	Rail	14[illegible]
Wilkes-Barre to New York	do	192
Wilkes-Barre to Mauch Chunk	do	55
Wilkes-Barre to Baltimore	Canal	216
Shamokin to Baltimore	Northern Central Railroad	158

The following statement of the distribution of the output of anthracite in 1883 has been prepared by Mr. F. E. Saward:

General distribution of anthracite in 1883.

Destination.	Long tons.
Competitive (including tonnage passing out of capes of Delaware to New York harbor, to points on Hudson river, Long Island sound, and the Atlantic coast north of Point Judith)	13, 148, 185
Western (including tonnage to points in the United States west of Buffalo and the Detroit river, Erie, Pittsburgh, and Baltimore)	2, 537, 174
Canadian (including all tonnage by lake and rail to points in the Dominion of Canada)	690, 498
Southern (estimated tonnage to all points in Delaware, Maryland and the territory bounded by the Ohio and Mississippi rivers on the north and west and the Gulf of Mexico on the south)	1, 284, 093
Pacific coast	24, 630
Local (embracing all coal consumed in Pennsylvania, New York, and New Jersey)	14, 070, 019
Foreign	38, 428
Total tonnage in 1883	31, 793, 027

Sizes of anthracite.—At one of the largest collieries in the anthracite coal field the percentages of the various sizes shipped to market in 1882 were carefully recorded, with the following result:

Percentage of marketable sizes of anthracite.

Sizes.	Quantity.		Per cent.
	Short tons.	*Cwts.*	
Lump	93,794	14	13.5
Steamboat	2,227	16	.3
Broken	143,068	05	20.0
Egg	88,385	07	12.8
Stove	97,194	61	14.0
Chestnut	155,604	03	22.4
Pea	113,920	03	16.4
Total	694,194	09	100.0

Wages in anthracite mining.—The following tables from the volume of Industrial Statistics, published by the secretary of internal affairs of Pennsylvania, show the condition of anthracite coal miners, and other employés about the mines, with regard to wages in 1881:

Exhibit of highest average wages paid in the anthracite coal mines of Pennsylvania, based on full working time.

Employés.	Day.	Week.	Year.
Miners on contract	$2.70	$16.20	$842.40
Miners on wages	2.00	12.00	624.00
Laborers, inside	1.78	10.68	555.36
Laborers, outside	1.40	8.40	436.80
Boys	.65	3.90	202.80
Drivers and runners	1.43	8.58	446.16
Firemen	1.58	9.48	492.96
Engineers	1.88	11.28	586.50
Blacksmiths	1.91	11.46	595.92
Slate pickers, boss	1.55	9.30	483.60
Slate pickers, boys	.50	3.00	156.00

Exhibit of actual wages paid in the anthracite coal mines of Pennsylvania, based on actual time employed.

Employés.	Day.	Week.	Year.
Miners on contract	$2.70	$8.84	$459.68
Miners on wages	2.00	7.00	364.00
Laborers, inside	1.78	6.14	319.28
Laborers, outside	1.40	4.91	255.32
Boys	.65	2.07	107.64
Drivers and runners	1.43	5.32	276.64
Firemen	1.58	5.73	297.96
Engineers	1.88	8.84	459.68
Blacksmiths	1.91	7.16	372.32
Slate pickers, boss	1.55	5.60	291.20
Slate pickers, boys	.50	1.70	88.40

The great difference shown in these tables between the rates of wages and the actual earnings is accounted for by the difference between the theoretical number of working days in a year and the average number of days in each year that the collieries are actually operated. The latter number of course varies.

Working records.—The following table, prepared by the Bureau of Industrial Statistics of Pennsylvania, shows the number of collieries, days in operation, number of employés, wages paid, and coal produced in the anthracite mines of Pennsylvania for 1884:

Condition of the Pennsylvania anthracite mines in 1884.

Localities.	Number of collieries.	Average number of days in operation.	Number of persons employed.	Amount paid in wages.	Number of tons of coal mined.
Schuylkill region.					
Columbia	8	170	2,180	$694,799	673,099
Dauphin	3	267	1,909	591,571	552,409
Northumberland	27	197	7,199	2,651,079	2,098,712
Schuylkill, part of	82	186	19,099	6,981,812	5,628,904
Total for region, 1884	120	190	30,387	10,919,261	8,953,124
Lehigh region.					
Parts of Carbon, Luzerne, and Schuylkill counties: Total for region, 1884	52	173	13,956	5,159,924	4,154,262
Wyoming region.					
Lackawanna and part of Luzerne county: Total for region, 1884	109	185	38,973	13,827,077	12,544,298
Grand total, 1884	281	185	83,316	29,906,262	25,651,664
Grand total, 1883	310	221	87,308	33,597,253	30,154,546
Decrease in 1884	29	36	3,992	3,691,991	4,502,882

In explanation it is stated that "the above report was obtained from all the operators reporting in 1883, together with some who had not reported before. The decrease since 1883 can be accounted for by depression in trade and by sales of collieries formerly owned by individuals to large companies. Some of them were shut down to restrict production. We have given the returns by counties whenever practicable. In the Lehigh and Wyoming regions the returns were of such a nature that it was not practicable to tabulate by counties. To the above total of coal mined there should be added 6 per cent. for coal consumed or sold at collieries."

Prices.—The following figures give the range of prices of anthracite during the years named. The unit is the long ton, and the delivery is free on board vessels in New York harbor.

Prices of anthracite at New York City in 1882, 1883, *and* 1884.

Grades.	Lump.	Grate.	Egg.	Stove.	Nut.
1882.					
Free-burning (lowest)	$3.90	$3.90	$3.90	$4.00	$3.90
Free-burning (highest)	4.30	4.30	4.55	4.85	4.75
Hard white-ash (lowest)	4.85	4.25	4.25	4.25	3.90
Hard white-ash (highest)	5.15	4.50	4.70	4.90	4.70
1883.					
Free-burning (lowest)	3.90	3.90	4.00	4.20	4.20
Free-burning (highest)	4.30	4.30	4.55	4.85	4.75
Hard white-ash (lowest)	4.85	4.10	4.10	4.35	4.10
Hard white-ash (highest)	5.15	4.50	4.70	4.90	4.70
1884.					
Free-burning (lowest)	3.80	3.80	3.80	4.15	4.00
Free-burning (highest)	3.80	3.80	3.80	4.40	4.15
Hard white-ash (lowest)	4.75	4.10	4.10	4.15	4.00
Hard white-ash (highest)	4.75	4.10	4.10	4.40	4.15

Mr. Saward says with reference to these figures: "It must be borne in mind that at no time within the years named were the circular rates actually realized; the divergence therefrom gradually became greater, and it is not saying too much to remark that during the latter part of 1884 there was a difference of 30 cents on grate and egg and 40 cents on stove and nut per ton between the circular and the actual quotations; the circular showing an advance of 25 cents per ton on the domestic sizes made on the 1st of July was a practical nullity."

PENNSYLVANIA—BITUMINOUS.

The Appalachian field, from which more bituminous coal has been mined than from any other, is one of considerable dimensions, extending over portions of nine States. Its shape is difficult to describe. Its general line of direction is from northeast to southwest. Commencing in several detached deposits in northeastern and north-central Pennsylvania, it rapidly broadens until it spreads over a large part of the western end of the State and covers about one-fourth of Ohio. Narrowing slightly, it passes southwest through Ohio and West Virginia. Passing into Kentucky on the west, and including within its eastern boundary a small portion of Virginia, it rapidly narrows until its width in Tennessee is less than one-fourth of its greatest width. The deposits then can be traced into Alabama, passing across the northwestern corner of Georgia in their course. In northern Alabama the field spreads out again, covering quite a considerable area, but abruptly ends with this expansion.

The total area of the Appalachian field is estimated at 59,435 square miles, which is distributed among the States over which it passes as follows:

States.	Square miles.	States.	Square miles.
Pennsylvania	12,302	Tennessee	5,100
Ohio	10,000	Georgia	170
Maryland	550	Alabama	5,530
West Virginia	16,000		
Virginia	1,000	Total	59,635
Kentucky	8,983		

Coal area of Pennsylvania.—The bituminous coal district of Pennsylvania, the northeastern end of the great Appalachian coal field, occupies about one-half the area of the State, being bounded on three sides by the States of New York, Ohio, West Virginia, and Maryland, and on the east by the Alleghany mountains. It also includes the mountain lands of Tioga, Lycoming, Bradford, and Sullivan counties, extending very nearly to the northeast corner of the State. The counties of Bradford, Sullivan, Lycoming, Clinton, Centre, Huntingdon, and Fulton, forming a crooked belt across the State from northeast to southwest, are the most easterly counties containing bituminous coal; in these, and in every county west of the belt so formed, with the sole exception of Erie county, bituminous coal is found in greater or less quantity.

In a commercial sense, however, the productive bituminous coal field of Pennsylvania cannot be said to be of so great extent as this. The general southerly dip of the strata in the district under consideration, and the outcropping of lower and lower formations as we progress northward through the State, indicate that at an early period in the earth's history the northern part of the State was lifted high above the southern. Erosion and denudation then took place, the northern portion of the State being entirely deprived of many of the strata which exist undisturbed in the more southern counties. Accordingly, the counties in the northern part of Pennsylvania west of the line described contain coal only in small patches, having been deprived, in the manner described, of nearly all the deposits which once existed in that part of the country. The true bituminous coal-producing district, then, is not synonymous with the part of the State covered by the counties which contain coal, but is much more limited. Constructing, as before, a belt of counties which shall be the boundary of the district, we name, commencing at the western boundary of the State, the following: Mercer, Butler, Clarion, Jefferson, Clearfield, Cambria, and Somerset, the last on the southern border. These counties, and all those west and south of the belt they form, constitute the bituminous coal district of Pennsylvania. A small part of Elk, and the four northern townships of Centre county, should, speaking precisely, be included in the district, and it must be remembered that several of the outlying deposits, such as the Broad Top field in Huntingdon, Bedford, and Fulton counties, and the Blossburg field in Tioga county, are of no small importance in a commercial way.

Across the district thus bounded lie the bituminous coal measures, in six principal basins, arranged in concentric curves of wide sweep, and separated by five great anticlinal waves. Lack of sufficient data prevents the tracing of these grand anticlinals throughout the State, but in general their persistence is remarkable. Laurel hill, the first mountain range west of the Alleghany mountains, forms the northern part of the first anticlinal axis (the southern portion not being exactly identified) and separates the first and second basins. Chestnut ridge forms the second axis. The third anticlinal wave, crossing Clearfield, Jefferson, Indiana, Westmoreland, and Fayette counties, is a very persistent axis. Of it Mr. Franklin Platt says: "The perfect straightness and regularity of this remarkable anticlinal is as wonderful as any phenomenon in geology. From where it enters the State across the Virginia line, to where it leaves Clearfield and enters Elk county, it runs 100 miles in an absolutely straight line." The fourth anticlinal axis has been carefully traced over but a part of its course; but the fifth axis is very distinct, and seems to be even more remarkable than the third axis, running nearly 150 miles without any such bend as at one point characterized the other.

Varieties of Pennsylvania bituminous coal.—The coal field of Pennsylvania contains almost every possible variety of bituminous coal. The greater part of the coal mined in this field is true bituminous coal, containing 20 per cent. and upward of volatile combustible matter; but in the detached deposits of Tioga, Bradford, and Huntingdon counties, and along the summit of the Alleghany mountains, the coal has a semi-bituminous character, containing only from 15 to 18 per cent. of volatile matter. The bituminous coals of Pennsylvania are known the country over for their admirable qualities. Coal for domestic use, steam coal, gas coal, coking coal, blacksmithing coal, all are found in wonderful variety and profusion in the Pennsylvania measures, and of unsurpassed quality for each purpose. To the cities of the Atlantic coast, to those of the extreme South, and to those of the Far West, Pennsylvania coal goes constantly, and is in steady demand.

Reserves.—Some twenty-one or twenty-two coal seams of commercial importance have been found and named in the bituminous field of Pennsylvania. These have been in most cases traced with much certainty throughout the district, nearly every bituminous deposit known to exist in the State being with more or less certainty identified with some one of them. The quantity of available coal contained in these seams has been carefully estimated by Dr. H. M. Chance, assistant geologist of the State Geological Survey, and a statement prepared by him is subjoined. It should be stated that no attempt is made in this table to show the total amount of bituminous coal contained in the deposits of Pennsylvania; the information it gives is of much more value, being in respect of the total amount of that coal alone which is accessible and workable, and of commercial value.

Reserves of bituminous coal in Pennsylvania.

Beds.	Long tons.
Upper Barren Measures:	
Washington bed, 3 to 3½ feet..	787, 200, 000
Upper Productive Measures:	
Waynesburg bed, 3 to 5 feet..	2, 126, 400, 000
Uniontown bed, 2 to 3 feet....	312, 000, 000
Sewickley bed, 3 feet.	432, 000, 000
Redstone bed, 2 to 3 feet......	326, 400, 000
Pittsburgh bed, 6 to 12 feet...	10, 438, 800, 000
	13, 635, 600, 000
Lower Barren Measures:	
Bush creek, Coleman, etc., beds	878, 400, 000
Lower Productive Measures:	
In Westmoreland, Fayette, and Allegheny counties ...	2, 064, 000, 000
Millerston bed, 3 feet	28, 800, 000
Freeport upper bed, 3 to 5 feet.	3, 764, 800, 000
Freeport lower bed, 2 to 6 feet.	2, 385, 600, 000
Lower Productive Measures:	
Kittanning upper, bed, 2 to 4 feet	1, 596, 000, 000
Kittanning middle bed, 2 to 3 feet	829, 800, 000
Kittanning lower bed, 2 to 6 feet	4, 225, 200, 000
Clarion coals, 2 to 3 feet	696, 000, 000
Brookville bed, 2 to 4 feet....	1, 627, 200, 000
	17, 217, 400, 000
Conglomerate series:	
Mercer coals, 2 to 3 feet......	932, 600, 000
Quakertown bed, 2 feet......	57, 600, 000
Sharon coal horizon, 2 to 3 feet..........................	38, 400, 000
	1, 028, 600, 000
Grand total.................	33, 547, 200, 000

The total available tonnage may be divided thus:

Classification of beds.	Long tons.
Beds over 6 feet thick	10, 957, 200, 000
Beds from 3 to 6 feet thick	19, 586, 800, 000
Beds from 2 to 3 feet thick	3, 003, 200, 000
Total	33, 547, 200, 000

"Excluding coals less than 3 feet in thickness," says Dr. Chance, "we have an available tonnage of 30,544 billion tons, and, assuming that 75 per cent. of this can be won in mining, we have 22,908 billion tons as the possible output from seams 3 feet or more in thickness. Probably two-thirds of this amount lies favorably situated for mining, and at ordinary prices for labor can be mined and placed on the cars at an average cost not exceeding $1 per ton; but the remaining third lies beneath water level, or beneath a thick covering of superimposed measures, and will probably cost from $1.25 to $1.50 per ton, at the present price of labor. The two-thirds, 15,272 billion tons, accessible above water level, and contained in beds not less than 3 feet thick, is sufficient to maintain the present average yearly output from Pennsylvania for about eight hundred years, or to supply the whole world for fifty years."

Sharon seam.—The lowest bituminous coal seam worked in the State (in a geological sense) is the Sharon seam, occurring in workable quantity only in Mercer county; its geological position being immediately above the Sharon Conglomerate, which lies at the bottom of the Great Conglomerate series No. XII. This coal is very uncertain, being found in little patches or basins which have apparently no connection with each other; it is, however, highly valued, as it is generally a splint or block coal, making a fine blast-furnace fuel. The deposits are being exhausted rapidly, and it is estimated that the coal will all be extracted in at most fifty years at the present rate of production. In Ohio this is an important seam, and analyses are given of it under that head.

The Mercer Upper and Lower coals, two other seams of formation XII., attain considerable importance only in Mercer county, where, while widely spread and affording an abundant supply of domestic fuel, they are at best impure, and in McKean county, where their proximity to market enhances their value.

The Brookville bed, the lowest seam of the Carboniferous series, occurs in some fifteen counties of the State, ranking sixth among the productive seams. In Jefferson county, from whose seat of government it derives its name, it is nearly always impure, but is mostly of workable dimensions, and is the main source of the local supply. In Centre and Blair counties this bed is mined, and furnishes in some places quite pure coal, but in general it is sulphurous, in many places being too much so for use.

The Clarion bed is formed in two subdivisions in some of the western counties, the upper of which is known as the Scrubgrass coal. It sometimes furnishes coal of excellent quality, but the bed is usually thin.

Lower Kittanning bed.—The next seam in ascending order is the Lower Kittanning bed, which in point of resources probably ranks second only to the Pittsburgh vein. In the southwestern part of the State it is not met with in workable quantity in many places, although in Beaver county it is persistent, and is very valuable in the vicinity of the towns of Industry, New Brighton, and Beaver Falls. Passing northwestward it is exposed in Butler County, where it is workable over a small area, and is of great extent in Armstrong and Clarion counties. In the former, while regular and persistent, it is somewhat impure; but in Clarion county it is spread over a large territory, and is a good steam coal. In Jefferson, Indiana, and Clearfield counties it is not a bed of great value, and while good in Centre county, is but slightly exposed. In Blair county it is of much importance, being known in some districts as the Miller seam. It is here mined in many places, is a very good coal, and is coked. Passing farther north and east the supposed equivalent of this vein is found in many of the detached deposits which outlie the northwestern edge of the Appalachian field. In Lycoming county the Big bed of the Little Pine creek basin is referred to this horizon, and contains large deposits of valuable coal. In Tioga county it is identified with the Bloss vein, producing the well-known Morris Run coal. In Sullivan county its supposed equivalent is mined in several places, and in Bradford county the Barclay coal, an admirable fuel for steam and household purposes, is referred to the Lower Kittanning horizon.

The Kittanning Middle coal is locally workable in Butler, Jefferson, Armstrong, Elk, Cameron, and Clarion counties, but is not a seam of very great importance, and does not contain nearly so much coal as many of the other veins.

Kittanning Upper seam.—This is noted not so much for the quantity as for the character of the coal it contains, nearly all the cannel coal in Pennsylvania, and in one or two localities a block coal, occurring at this horizon. In the extreme southwestern part of the State it is, of course, not found; but in Beaver and Lawrence counties, on the Ohio line, it is a bed of much importance. In Beaver county it is occasionally uncertain; but, in the main, is a good coal, and in many places is very good and rich, notably on the Big Beaver river. On the Little Beaver river, three miles below Darlington, it appears in the form of a great cannel deposit, averaging 7 feet in thickness, and is hence known widely as the Darlington seam. In Lawrence county it extends over a wide territory, and is from 2 to 4 feet thick. It varies in quality, but in some places is exceptionably pure, making a fine gas coal, and occurring in one locality as a genuine block coal. In Butler county, the Kittanning Upper bed is the chief source of supply; and here, too, is sometimes a cannel coal. In Armstrong county it is somewhat uncertain, and in some places is an impure cannel, but is fairly good in others.

In Clarion and Jefferson counties the seam is small and unimportant. In Indiana county it is occasionally good, and in Clearfield county, while often slaty, is in some localities of great importance. In Cambria and Blair counties it is not mined. In Centre county it is an exceedingly important deposit, being the chief bed of the well known Snowshoe basin. Persistent, everywhere above water, easily accessible, thick, and of excellent quality, it is here as valuable a deposit of coal as falls to the lot of any county in the State. It here justly receives the title of the "Big bed." In the Broad Top region of Huntingdon and Bedford counties the Barnet bed is supposed to be the equivalent of the Kittanning Upper coal, although some authorities identify it with the Kittanning Middle seam. Farther northwest it is of no importance, being seldom exposed.

The Freeport Lower coal is the next in ascending order, and ranks fourth in importance. It is persistent, but very irregular, in Butler county, being workable in but few places, but sometimes attaining great thickness, measuring 16 feet in one locality. In Clarion county it is of limited extent, but is very good, and has been used in blast furnaces, also being available for gas. In Armstrong county it is usually uncertain and somewhat impure, but is available in some places. In Jefferson county it is the source of supply of the Reynoldsville basin, and is the main seam in the county, being workable wherever the hills are high enough to contain it. In Indiana county it is of less consequence, but in Clearfield and Cambria counties regains its importance. In the former it is the celebrated Moshannon vein, being nearly always a good coal, while in the latter it is mined extensively by the Cambria Iron Company at Johnstown. In Centre county it is nowhere opened. It is identified by the best authorities with the Kelly seam in the Broad Top field. It is also workable in parts of Elk and Cameron counties.

The Freeport Upper coal is workable in parts of fifteen counties, and ranks third among the productive seams of the State. It is of considerable importance in the eastern half of Butler county, but west of this is of less value. In Armstrong county it is generally uniform, regular, and pure. In Clarion county the bed underlies a limited extent of territory, but the coal is very good, and has been used in blast furnaces. In Jefferson county it is unreliable, but in Indiana county it is the chief coal, being good and thick. In Cambria county it is a good steam coal, and is mined considerably; in Blair county, however, while possessing the same character and being generally 5 feet thick, it is not mined to any extent, owing to the great superiority of the Miller or Kittanning Lower seam. In Somerset county it has a fair thickness, and contains a considerable amount of available coal. In Clearfield and Centre counties it is generally good, but of limited extent and importance. A considerable amount of coal in the two Freeport beds is accessible in Allegheny county, but it is generally inferior in quality and receives little attention.

The Millerstown bed, the highest of the Lower Productive series, is locally workable in Butler county, and is not of wide importance.

In the Lower Barren Measures occur several beds in Indiana, Somerset, and Butler counties, attaining workable size over a limited area, and in Armstrong and Beaver counties there is also a small quantity of workable coal in these measures. These seams, however, will probably never attain great commercial importance, and will be mined chiefly to supply the local demand.

The Pittsburgh coal bed, at the bottom of the Upper Productive Coal Measures, is the best and most valuable seam of the bituminous coal area. It ranges from 3 to 9 feet in thickness, and, according to the estimates of Dr. Chance, contains nearly one-third of the available bituminous coal in Pennsylvania. Its most extensive areas are found in Fayette, Washington, Allegheny, Westmoreland, and Greene counties, small areas also occurring in Indiana, Somerset, and Beaver counties. The purity and quality of this coal and the excellent character of the coke made from it—the famous Connellsville—render it much more valuable than any other seam. This bed alone, of all the beds in the Upper Productive coal series, has such narrow limits of variation, as to be an available bed throughout the district, wherever it is within reach. It nowhere becomes too thin or too impure to repay working, and maintains its quality with remarkable persistence. The fact that it is accessible nearly all the way along the Monongahela river from the State line to Pittsburgh renders it immensely more important in a commercial way, owing to the cheap transportation which is thus afforded.

With rare exceptions this bed is double, consisting of a roof and a lower division, separated by a clay parting; and a bituminous shale, from 8 to 12 inches thick, is frequently found resting on the roof. The roof division of the vein varies greatly in thickness, ranging from 2 inches to 8 feet, with a generally greater thickness towards the north of the field. Occasionally it is a single bench, but commonly it contains two or more benches, separated by clay. The coal is invariably poor, owing to the large proportion of ash. The lower division of the vein varies from 3½ to 9 feet in thickness, and is divided by three persistent but thin partings into four benches. The top or "upper" bench is the thick bench, and usually yields the best coal. The second or "bearing-in" bench varies from 2 to 4 inches, but is invariably distinct, except where the bed is a block coal and all the partings are missing. The name is applied because on this bench the miner works in to gain a face against which to bring out the other portions of the bed. The coal is generally good, but in removal is reduced to slack. The third or "brick" bench is characterized by cleavage planes which break the coal into blocks in size and shape like a common brick, whence the name. It yields a good coal, hardly inferior to that from the "upper" bench. The coal of the "lower bottom" bench, the lowest, is generally inferior or worthless.

As stated, the total thickness of the Pittsburgh coal bed ranges from 3 to 9 feet. In the southeastern part of the district the total thickness is from 7 to 9 feet, being greatest at Brownsville, where the roof measures 4 inches and the lower division 9 feet. In the vicinity of Pittsburgh and the adjoining portions of Allegheny county it varies little from 5½ feet, while in northwestern Washington county it ranges from 3½ to 5 feet, the former thickness being found at Midway, on the Pittsburgh, Cincinnati and Saint Louis railroad, where the coal is a block.

The coal from the lower division of the Pittsburgh bed is somewhat brittle, rich in combustible matter, contains a variable percentage of sulphur, and cokes. In some portions of the district it exhibits layers of cannel near the top, and occasionally, as along the Panhandle railroad in Washington county, mentioned above, it becomes a very superior block coal.

The next three beds, in ascending order, are of but local importance. They are the Uniontown, the Sewickly, and the Redstone beds, the first two being locally workable in parts of Fayette and Greene counties, and the latter in Westmoreland and Allegheny counties.

The Waynesburg bed, the top coal seam of the Upper Productive Coal Measures, is a vein of great importance in Greene and Washington counties, and attains also a good thickness in Fayette and Westmoreland counties. According to Dr. Chance's estimates, it holds the fifth place among the coal beds of the State in point of available fuel.

In the Upper Barren Measures is found but one coal seam of commercial importance, the Washington bed, which attains its best development in Washington and Fayette counties, but is not persistent as a workable seam in any other county. This series of rocks contains several other seams, but they are usually very thin and of poor quality, although one, the Waynesburg A bed, may prove workable over a small area in Fayette county.

Production.—From the best sources of information the following statement of the production of bituminous coal in Pennsylvania has been prepared:

Output of bituminous coal in Pennsylvania since 1873.

Years.	Long tons.	Years.	Long tons.
1873	11,695,383	1879	14,500,000
1874	11,000,000	1880	18,000,000
1875	10,500,000	1881	20,000,000
1876	11,500,000	1882	22,000,000
1877	12,500,000	1883	24,000,000
1878	13,500,000	1884	25,000,000

The following table gives the detailed production of some of the most prominent bituminous coal districts of Pennsylvania, together with the production of Cumberland (Maryland) coal, and the imports of bituminous coal into the United States, as reported by the Pennsylvania Bureau of Statistics:

Statistics of many of the bituminous-coal districts of Pennsylvania, with the imports, and also the output of Cumberland coal, in long tons.

Years.	Blossburg.	Barclay.	McIntyre.	Broad Top.	Snow Shoe.	Clearfield.	Monongahela Slackwater.	McKean Co.	Westmoreland.	Imports.	Cumberland.
1840	4,235	....	....	....	....	....	....	....	....	162,867	....
1841	25,966	....	....	....	....	....	....	....	....	153,394	....
1842	13,164	....	....	....	....	....	....	....	....	141,521	1,708
1843	6,268	....	....	....	....	....	....	....	....	41,163	10,082
1844	14,234	....	....	....	....	....	....	....	....	87,073	14,890
1845	29,836	....	....	....	....	....	184,200	....	....	85,776	24,653
1846	16,519	....	....	....	....	....	311,156	....	....	156,853	29,795
1847	29,087	....	....	....	....	....	385,805	....	....	148,021	52,940
1848	33,762	....	....	....	....	....	392,774	....	....	196,168	79,571
1849	32,095	....	....	....	....	....	398,340	....	....	198,213	142,449
1850	23,161	....	....	....	....	....	491,918	....	....	180,439	196,848
1851	25,000	....	....	....	....	....	490,850	....	....	214,774	257,679
1852	20,000	....	....	....	....	....	585,233	....	....	183,0 5	334,178
1853	45,507	....	....	....	....	....	628,654	....	....	231,508	533,979
1854	70,214	....	....	....	....	....	693,278	....	....	252,865	659,681
1855	73,204	....	....	....	....	....	889,360	....	....	287,408	662,272
1856	70,669	2,295	....	42,000	....	....	353,364	....	....	293,507	706,450
1857	94,314	6,265	....	78,813	....	....	1,178,939	....	....	360,712	582,486
1858	41,894	17,560	....	105,478	....	....	1,027,866	....	....	396,628	649,656
1859	48,592	30,143	....	130,595	....	....	1,131,467	....	....	403,928	724,354
1860	90,918	27,718	....	186,963	....	....	1,517,909	....	....	389,986	788,909
1861	112,712	40,835	....	272,625	....	....	834,630	....	....	465,434	269,674
1862	179,334	52,779	....	333,606	8,260	7,239	743,358	....	....	541,099	317,634
1863	235,843	54,535	....	305,678	12,039	24,330	1,134,570	....	....	624,348	748,345
1864	384,977	62,058	....	686,645	33,503	65,380	1,402,828	....	....	597,738	657,996
1865	394,642	73,197	....	315,996	51,881	60,629	1,580,791	....	....	696,193	903,495
1866	411,759	99,453	....	265,720	70,890	107,878	1,704,212	....	....	643,294	1,079,331
1867	481,318	74,739	....	244,412	58,137	169,219	1,202,908	....	....	521,305	1,193,822
1868	693,328	73,675	....	280,936	60,149	171,238	1,812,040	....	....	402,299	1,330,433
1869	715,094	180,610	....	360,799	89,376	259,994	2,100,504	....	....	423,810	1,882,669
1870	733,035	273,335	17,808	313,425	85,276	379,863	2,303,856	....	....	420,683	1,717,075
1871	815,079	378,335	106,130	319,625	79,984	542,896	1,914,852	....	....	443,955	2,345,153
1872	849,262	382,842	171,427	297,473	68,988	431,915	2,291,220	....	....	490,631	2,355,471
1873	991,057	337,614	212,462	350,245	95,2 7	592,860	2,094,312	....	....	456,015	2,674,101
1874	796,388	337,062	138,907	226,693	63,540	639,630	2,503,504	....	952,971	498,028	2,410,895
1875	581,782	376,637	164,507	258,488	62,426	928,297	2,275,265	33,501	796,963	441,600	2,342,778
1876	616,984	361,138	208,701	225,803	51,399	1,281,861	2,495,800	81,830	900,139	488,132	1,835,081
1877	602,245	340,099	183,715	194,881	42,985	1,374,927	2,677,460	73,222	786,039	498,275	1,574,339
1878	652,597	314,320	154,205	213,272	29,168	1,295,201	2,797,530	72,098	692,586	566,938	1,679,322
1879	874,010	382,504	127,632	209,523	56,654	1,631,120	2,623,232	85,745	816,302	449,167	1,730,709
1880	921,555	462,806	216,225	2 7,186	56,020	1,739,873	3,361,634	100,046	943,177	577,458	2,136,160
1881	1,178,581	433,836	236,922	296,564	128,263	2,401,987	3,450,186	110,099	982,293	834,875	2,261,9 8
1882	1,165,604	398,576	209,858	370,211	233,708	2,838,970	4,057,384	73,834	1,278,121	774,425	1,540,466
1883	1,217,870	371,010	184,552	241,271	257,230	2,857,710	4,3 9,492	75,000	1,399,762	752,841	2,544,173
1884	1,018,342	314,481	84,274	236,220	183,271	3,173,363	3,170,900	100,000	1,320,186	800,968	2,934,979

Working records.—The following table shows the number of mines in operation, number of days in operation, hands employed, wages paid, and coal produced during 1884, compiled from returns made to the Bureau of Industrial Statistics of Pennsylvania:

Condition of the Pennsylvania bituminous-coal mines in 1884.

Counties.	Number of mines.	Average number of days operated.	Number of persons employed.	Amount paid in wages.	Number of tons of coal mined.
Allegheny	64	157	9, 228	$2, 983, 391	2, 863, 631
Armstrong	4	256	343	112, 822	170, 826
Beaver	6	159	535	167, 794	156, 695
Bedford	3	164	218	56, 021	69, 770
Blair	6	274	487	172, 723	208, 541
Bradford	3	232	610	305, 895	318, 575
Butler	5	179	339	117, 090	151, 335
Cambria	18	242	1, 141	808, 328	659, 843
Cameron	1	217	100	18, 729	13, 652
Centre	6	228	780	124, 142	216, 412
Clarion	9	188	747	649, 059	329, 973
Clearfield	39	183	3, 742	1, 105, 123	2, 177, 543
Elk	6	253	785	388, 998	413, 243
Fayette	64	235	6, 047	2, 584, 063	4, 041, 643
Huntingdon	8	224	451	164, 469	212, 527
Indiana	1	306	62	24, 148	30, 758
Jefferson	6	216	881	264, 877	450, 079
Lawrence	4	128	192	37, 382	42, 818
McKean	3	202	147	75, 348	78, 870
Mercer	13	160	882	293, 749	276, 350
Somerset	13	212	359	122, 086	269, 930
Tioga	6	171	2, 386	887, 366	931, 922
Venango	1	300	34	15, 825	15, 000
Washington	26	186	2, 499	702, 253	707, 262
Westmoreland	46	244	5, 911	2, 581, 095	3, 282, 733
Total for 1884	361	213	38, 906	14, 752, 786	18, 084, 941
Total for 1883	381	207	45, 454	17, 014, 624	18, 729, 817
Decrease from 1883	20	6	5, 548	2, 261, 838	644, 876

Wages and strikes.—The years 1883 and 1884 were marked for numerous dissensions between coal operators and miners in regard to wages. Trouble occurred in several districts, notably in Clarion, Elk, and Clearfield counties, in the railroad mines in Allegheny county, and along the Monongahela river in Washington and Fayette counties. The disturbances in the railroad mines around Pittsburgh began May 1, 1883, when some 6,000 men stopped work, in resistance to a reduction of the price paid for mining to 3 cents per bushel. Arguments were presented on the one side of pay already too small to provide necessities, and on the other of overproduction and declining prices. After numerous fruitless conferences between committees of operators and miners, a "trade tribunal" was formed under the Wallace act, and was licensed by the court. The tribunal, to aid them in coming to some conclusion, diligently collected much valuable information bearing on the subject of wages in the Pittsburgh and surrounding districts, but were none the more able to agree upon a price, and finally, under a provision of the Wallace act, appointed an umpire, Mr. John R. McCune, president of the Union National Bank of Pittsburgh, who, after duly considering the evidence placed before him, settled the question temporarily by "splitting the difference" and deciding that 3¼ cents per bushel should be the rate paid for mining. This rate was generally accepted, and prevailed for some time.

In 1884 another reduction was decided upon by the operators and objected to by the miners. After much dissension the tribunal was revived, and Mr. Joseph D. Weeks, secretary of the Western Iron Association, was selected as umpire. This gentleman rendered a very able and logical decision, fixing the rate at 2½ cents per bushel for the time at which the decision was made, and presenting a carefully considered sliding scale for the future adjustment of wages, based on the selling price of coal at Pittsburgh. This scale ran from $7.75 per 100 bushels, at which price the wages for mining were to be $4.60, to $4, at which the wages were to be $2. This decision was made February 11, 1885. Unfortunately for the miners, they came to the conclusion that they could by striking obtain better rates than the scale provided, and accordingly the award was not approved and a strike was begun, which lasted until the latter part of April, when the miners yielded and work was resumed in the railroad pits, generally at lower prices than the scale presented by the umpire provided.

Disputes between the operators and miners in the "Fourth pool" of the Monongahela river—that part of the country lying along the river between dams Nos. 4 and 5—arose in 1883, and arbitration committees were appointed. These were unable to agree, and selected Mr. Weeks as arbiter or umpire, the proceedings, however, not being under the Wallace act, but of the nature of private arbitration. Mr. Weeks gave his decision on December 22, in favor of the miners' position, the question being the proportion which should exist between the price paid for mining in the "Fourth pool" and that paid in the "Second pool" The miners, who held that the difference between the two prices should remain ½ cent, were upheld by the decision. The operators refused to abide by the award, and a strike occurred. Some of the mines succeeded in inducing their workmen to resume at 2 cents per bushel, the price demanded by the operators, and the striking miners strenuously endeavored to induce all who were at work to "come out" and render the strike general. "Camping," or locating a camp of striking miners adjacent to the works the miners at which were not striking, and constantly arguing and urging them to strike, was one of the methods adopted by the strikers. All expedients finally failed, however, and on October 1, 1884, all the "Fourth pool" miners went to work at 2 cents.

A serious strike occurred at Du Bois, Clearfield county, in 1883, in which the employés of sixteen mines were engaged, numbering in all some 25,000 men. The strike lasted about eight weeks at some mines and about twelve weeks at others. The question at issue at first was, as in the "Fourth pool" troubles, the relative price in comparison with other districts. Other disputed points turned up at various mines, and the trouble became somewhat complicated, but ended in the discomfiture of the strikers.

The following table showing the rates of wages paid in the railroad mines of Allegheny county for a series of years has been prepared by Mr. Saward:

Prices paid for mining Pittsburgh coal.

[Price of coal mining on railroads entering city of Pittsburgh, for coal run over a 1½-inch screen. Per 100 bushels, 76 pounds per bushel.]

Months.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
January	$2.75	$2.50	$3.00	$2.66	$2.66	$3.50	$3.50	$4.00	$3.50	$3.50
February	2.50	2.50	3.00	2.66	2.66	3.50	3.50	4.00	3.50	3.50
March	3.00	2.50	2.50	2.66	2.50	3.50	3.50	4.00	3.50	3.50
April	3.00	2.50	2.50	2.50	2.28	*a*3.50	3.50	*b*4.00	3.00	3.00
May	3.00	2.50	2.50	2.50	2.28	3.00	3.50	4.00	3.00	3.00
June	3.00	2.50	2.50	2.50	2.28	3.00	3.50	4.00	3.00	3.00
July	3.00	2.50	2.50	1.90	2.28	3.00	3.50	4.00	3.00	3.00
August	3.00	2.50	3.00	1.90	2.28	3.00	3.50	3.50	3.25	3.00
September	2.50	2.50	3.00	2.28	2.40	3.00	3.50	3.50	3.25	3.00
October	2.50	2.50	3.00	2.28	2.75	3.50	4.00	3.50	3.50	3.00
November	2.50	2.37	3.00	2.28	*c*3.50	3.50	4.00	3.50	3.50	3.00
December	2.50	*d*2.00	3.00	2.28	3.00	3.50	4.00	3.50	3.50	3.00
Average	2.77	2.45	2.79	2.36	2.57	3.29	3.62	3.80	3.28	3.12½

a $3.50 until April 26; then reduced to $3.
b Strike in all Pan-handle mines from April 1 to August 15, against a reduction from $4 to $3.50. Miners accepted reduction.
c Paid according to decision of board of arbitrators.
d Three prices this month, viz., $1.75, $2, and $2.25; average, $2.

Ranged from $1.75 (in December, 1876) to $5 (1872 and 1873).
General average for ten years, $3; for last five years, $3.42.
At mines that pay for the unscreened coal the price is adjusted as follows: 8 cents per ton of 2,000 pounds for each 50 cents per 100 bushels of 1½-inch screen coal.

Price of coal at Pittsburgh.

[Price of coal run over 1½-inch screen, free on board cars union yard, Pittsburgh. These prices are for 100 bushels, 76 pounds per bushel.]

Months.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
January	$5.50	$5.50	$6.00	$5.75	$5.00	$6.75	$7.00	$7.50	$6.50	$6.25
February	5.50	5.50	5.75	4.75	5.25	7.00	7.00	7.50	6.50	6.25
March	6.50	5.25	5.75	4.75	5.00	6.75	7.00	7.00	6.50	6.00
April	6.50	5.25	5.75	4.75	4.75	*a*6.75	7.00	7.00	6.00	5.50
May	6.25	5.25	5.75	4.75	4.75	6.00	6.50	7.00	6.00	5.00
June	6.25	5.25	5.25	4.75	4.75	5.75	6.50	7.00	6.00	5.00
July	6.00	5.25	5.25	4.00	4.75	5.75	6.00	7.00	5.50	5.00
August	6.00	5.25	5.75	4.00	4.75	5.75	6.00	6.50	5.50	5.25
September	5.50	5.26	5.75	4.00	4.75	5.75	6.50	6.50	5.75	5.25
October	5.50	5.25	5.75	4.25	5.50	6.25	7.40	6.50	6.00	5.50
November	5.50	5.25	5.75	4.25	*b*6.60	6.50	7.40	6.00	6.25	5.50
December	5.50	4.75	5.75	4.25	6.00	6.50	7.25	6.00	6.25	5.50
Average	5.87	5.25	5.60	4.52	5.15	6.29	6.79	6.79	6.06	5.50

a Price until April 20; then reduced to $6.
b Price advanced on account of decision of arbitrators.

General average for ten years, $5.78; average for last five years, $6.28.
The above prices are for coal delivered in individual cars only.

RHODE ISLAND AND MASSACHUSETTS.

The New England basin has been estimated to cover 500 square miles in the States of Massachusetts and Rhode Island. The coal, of which about a dozen beds exist, is described as a plumbaginous anthracite. The whole thickness of the Coal Measures of this field has been estimated at 6,500 feet, and that of the Coal Measures proper at 2,500 feet.

Paleontological evidence seems to indicate that the coal corresponds with that of the well-known Mammoth anthracite vein and the Lower Freeport bituminous vein, in Pennsylvania.

TENNESSEE.

The area of the Appalachian coal field contained in the State of Tennessee is 5,100 square miles. The same formations in which coal is found in Pennsylvania contain coal in this State, and, in addition, formation XI., the Umbral red shale of Rogers, below the Conglomerate, contains several workable seams of coal of excellent quality. The usual classification of the Coal Measures has been into Upper and Lower Measures, the division being made on the thick Conglomerate which forms the Cumberland table land or plateau. The more proper classification, and one more in unison with those of other States, is into Upper, Lower, and sub-Conglomerate Measures. This would seem to be more proper, as it is stated that the fossils of the seams immediately above the Conglomerate are identified with those of the Lower Coal Measures of Ohio and Pennsylvania. The chief seam of coal in this State is the Sewanee seam, which furnishes a greater amount of coal than any other single seam in Tennessee, and has all the qualities that combine to make a useful and valuable coal. It varies in some of its characteristics and constituents in different localities, but in general is a good steam-making coal, makes a hot, durable fire in a grate, and is nearly free from sulphur; it also makes a good coke. It is the only seam in the Lower Measures (adopting the more accurate classification) which is of value in the southern part of the State, and is mined extensively in the vicinity of Tracy City, in the Little Sequatchee valley, and at many other points about the headwaters of the same stream, as well as at other places in the southern portion of the field. In the northeastern portion of the field the measures above the Conglomerate contain eight workable seams. The sub-Conglomerate veins are usually three: the slate vein, the lowest, is from 1 to 3 feet thick, and is very hard and lustrous; the Cliff vein, lying 60 to 80 feet above the slate vein, varies from 1 to 12 feet in thickness, and in hardness resembles that of the slate vein; the sub-Conglomerate vein, just below the division between the Lower and sub-Conglomerate Coal Measures, is too thin to work at the outcrop, but is very persistent and affords excellent coal. The transportation facilities, together with the production of coal, are increasing rapidly.

Production of coal in Tennessee since 1873.

Years.	Long tons.	Years.	Long tons.
1873	350,000	1879	450,000
1874	350,000	1880	641,042
1875	360,000	1881	750,000
1876	550,000	1882	850,000
1877	450,000	1883	1,000,000
1878	375,000	1884	1,200,000

TEXAS.

The coal fields of Texas are coming quite prominently to the front, of late years. There are three very large and promising fields in the State—the Red River, the Rio Grande, and the Pecos districts. In the first of these districts are embraced the counties of Montague, Clay, Wise, Jack, Young, Shackleford, Palo Pinto, Parker, Erath, Comanche, Eastland, Callahan, Brown, Coleman, Runnells, McCulloch, San Saba, and Menard. The same coal also crops out at various places in Burnet, Mason, Llano, and Tom Green counties, and they may therefore be considered a part of the same district.

As this State has never yet had a geological survey, the extent of her coal strata is not well defined. It is supposed, however, to embrace about 30,000 square miles in the northern and western portions of the State. Over this great area coal has been found at many places, but at no place has it been mined except to a small extent. It is a bituminous coal, and almost, if not quite, precisely similar to the McAlister coal of the Indian Territory. Some anthracite is said to have been found in this coal field. The railroads are now penetrating the coal formations of Texas, and this great source of wealth will soon doubtless be rapidly developed. In addition to the true coals of Texas, there is an immense bed of lignite, which extends apparently across the entire State from northeast to southwest. It is said to be at some points 20 feet thick. This lignite much resembles cannel coal. Extensive developments of superior coal have been made at and near Laredo. This city is on the line of the Rio Grande and Pecos railway. On this railway, near Laredo, and on the coal lands belonging to the company, several mines have been opened, two of which on the railroad company's land, known as the Hunt mines, were recently producing 130 tons per day, which output could easily be doubled. The thickness of coal in the Hunt mines is from 18 to 26 inches. Three workable veins of coal are believed to exist on the property, tests having indicated their presence. The price paid for mining is necessarily high, but such is the scarcity of fuel in this region that prices sufficient to realize profit can easily be obtained. The coal shows a marked absence of sulphur and burns freely. This State probably produced 125,000 tons of coal during 1884.

UTAH.

The earliest coal developments made in Utah were at Coalville, Summit county, where in 1864 operations were commenced at what is now the Acme mine of the Acme Coal Company. The vein here is 12 feet thick, being opened at two places. About 100 men are employed, and the product is consumed chiefly at Park City in operating silver mines and mills. Many other mines are located near Coalville, on the Weber river.

The Pleasant Valley coal is also a well-known coal, and is probably the best coal mined in Utah. The mines are two in number, are owned by the Denver and Rio Grande Railway, and are located at Scofield, about 115 miles southeast of Salt Lake City. Other companies have opened mines in the same vicinity, and the production is becoming very large.

Another less-known but old mine is the San Pete Valley mine, in San Pete county, nearly 100 miles south of Salt Lake City. This mine has been opened in a small way nearly twenty years, and is worked only to supply a local demand. The vein is 5 feet thick, and affords a hard, bituminous coal.

South of Pleasant valley a few miles is Castle valley, where, as well as in Iron county, farther south, very large deposits of coal have been discovered. The remoteness of these from transportation will, however, long delay their development.

A full discussion and analyses of some Utah coals, with other particulars, will be found in the first volume of this series.

VIRGINIA AND WEST VIRGINIA.[a]

Owing to the fact that five-sixths of the coal area of Virginia lie in the great Appalachian basin, and are intimately connected with the portion of that basin which covers the State of West Virginia, the two States will be considered together. In these two States are contained about 17,000 square miles of the Appalachian basin. The principal districts in which the bituminous coals of this basin are mined are along the Ohio river, along the Baltimore and Ohio railway from Preston county, West Virginia, west to the Ohio, and on the Great Kanawha and New rivers, this latter district extending south into Virginia and being by far the most important. The Elk Garden field, on the upper Potomac river, on the dividing line between the two States, is growing in importance. In the northern part of the division of the Appalachian basin contained in these two States the coals of formation XIV. are mined, and in the southern part the Lower Measures and the Conglomerate, formations Nos. XII. and XI., furnish the chief supply.

The Pittsburgh coal bed is of great importance in the northern part of West Virginia, being the chief source of supply. It is generally of great thickness, averaging from 8 to 10 feet. It is of great value at Wheeling, furnishing fuel to supply her extensive iron and nail mills, blast furnaces, and glass works. It is the coal which is mined chiefly along the Ohio river, and is the chief product of the mines along the Baltimore and Ohio railway, the product at Fairmount, Clarksburg, and Newburg being largely used for making gas. Passing farther east, it is found at intervals throughout the Potomac-Cheat field, attaining in the Elk Garden field a thickness of 14 feet of merchantable coal, rarely excelled as a steam coal. Passing on to the northeast, it ap-

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[a] See also the discussion of coal mining in the Kanawha valley of West Virginia, by Mr. Stuart M. Buck, page 131 of this volume.

pears as the well-known coal of the Cumberland or George's Creek district, in Maryland.

The basin of the Great Kanawha river, however, as has been mentioned, is the chief location of the bituminous wealth of Virginia and West Virginia. In this basin the Coal Measures of the great Appalachian field attain their greatest thickness, contain the largest number of workable beds of coal, and aggregate the greatest thickness of coal.

The Coal Measures of the Great Kanawha basin have been carefully studied, and the several beds identified in most cases with those of the Pennsylvania bituminous-coal district, by Prof. I. C. White, of the United States Geological Survey, to whom this report is indebted for a large proportion of the information which follows in regard to the Kanawha field.

The following summary is compiled from a generalized section of the Coal Measure rocks along the Great Kanawha made by Professor White, and shows in a general way the number and total average thickness of the several beds in the district, together with the thickness of the formations which contain them: No. XV., 274 feet of measures, 2 beds, 14 feet of coal; No. XIV., 806 feet of measures, 5 beds, 18 feet of coal; No. XIII., 976 feet of measures, 8 beds, 26 feet of coal; No. XII., 1,310 feet of measures, 4 beds, 10 feet of coal.

In many cases beds are found ranging much above the thickness taken as the average, and also are often found displaying a division into two or more beds; the above is simply an exhibit of the average number and thickness of the beds.

Commencing with the Upper Coal Measures, formation XV., two beds of coal are found, but one of which is of commercial importance.

The Waynesburg coal, at the top of this group, is found along the river hills near the center of the great Appalachian trough, and was once opened and mined to a small extent near Arbuckle. It does not exceed 3 feet in thickness anywhere on the Kanawha. Not more than half of this is pure enough to use, and the bed is often absent entirely, so that economically it is of no importance.

The Pittsburgh coal, the lowest member of No. XV., has been successfully mined for many years at Raymond City, where, aside from the roof coal, it has a thickness of 5 to 6 feet. Its final outcrop to the south is on Two-mile run, below Charleston, 4 miles back from the river, and hence it has been mined only in a small way, for country use and for hauling to Charleston, 6 miles distant. The coal is a "splint" of most excellent quality on Two-mile run, and is greatly prized for domestic purposes. The thickness of the main bench is seldom less than 5½ feet, and often exceeds 6, and since its area spreads from Two-mile across to the Pocatalico at Sissonville, and thence to the Kanawha at Raymond City, there is evidently an important coal field awaiting development here when railroad facilities shall have rendered it accessible. When followed down the Kanawha river from the region of Raymond City, the Pittsburgh coal develops a tendency to patchiness, that is, it is either absent entirely from large areas or too thin and uncertain to warrant mining. Just before it disappears below the Kanawha river, however, it comes in again 5 miles below Winfield, and has there been mined by Mr. Boyer, at Oak Ridge.

The Lower Barren Measures contain five coal horizons. Of these, the upper two, corresponding to the Elk Lick and Bakerstown beds, furnish nowhere in the region coal of any commercial value. The Brush Creek bed, however, in the Mahoning sandstone group, is as persistent here as in Pennsylvania and Ohio. This coal comes up to the Kanawha below the mouth of Elk river, and below Charleston station exhibits the following structure:

	Ft.	In.
Coal	0	6
Black, sandy slate	2	6
Coal	1	6
	4	6

This coal is thin, irregular, and of no importance in the immediate vicinity of Charleston, but going south from there 3 miles it thickens up to from 3 to 4 feet and has been successfully mined for local use. Still further south, in the vicinity of North Coalburgh, it swells up to an immense thickness, and is usually called the "Big bed," exhibiting the following structure there at one opening:

	Ft.	In.
1. Coal	1	6
2. Black slate	0	6
3. Coal (good splint)	4	2
4. Shale	2	6
5. Coal	0	6
6. Shale	5	0
7. Coal	3	6
	17	8

No. 3 is the valuable portion of the Brush Creek bed, since it is a "block" or "splint" coal of very fair quality. It has not been mined for shipment heretofore, because of its inaccessibility, occurring as it does in the tops of the hills, 750 feet to 800 feet above the Kanawha river.

This bed, which is nearly always a splint coal, will doubtless furnish a considerable quantity of valuable fuel in the region southwest from the Kanawha, since at the head of Cabin creek it exhibits 5 feet of good coal in one bench, while on Huff Creek mountain, near Guyandot river, Wyoming county, it is reported as 10 feet thick. This also seems to represent one, or perhaps two, of the beds of splint coal reported along Elk river, since it is double or triple nearly everywhere.

The two lower coal beds in formation XIV. are new elements in the Barren series, and have been named by Professor White the Upper and Middle Cannelton coals, from the locality where the former has long been mined. It is an excellent quality of splint, having been used successfully in the raw state for smelting iron ore. The entire bed is about

6 feet thick at Cannelton, but the upper portion is split up with partings, so that only 4½ feet of good coal is obtained from the bed.

Near the mouth of Armstrong creek, at an elevation of more than 1,200 feet above the Kanawha river, this bed shows a thickness of 54 inches of clean coal; northward from Cannelton it becomes thinner and poorer in quality, and in the vicinity of North Coalburgh is only from 3½ to 4 feet thick, and is not there regarded as a workable bed.

The Middle Cannelton coal is a valueless seam which immediately overlies the "Black Flint," at the bottom of the Barren Measures, and seems to be rather persistent, but being slaty and worthless has never been mined.

A remarkable feature in the geology of West Virginia is the great thickness of certain series of strata as compared with the same formations in Pennsylvania. Thus, the Barren Measures average about 800 feet in thickness in West Virginia, but average in western Pennsylvania but 600 feet, and in Ohio much less. Similarly, the Lower Coal Measures sometimes show in this State a thickness of 1,100 feet, while in western Pennsylvania the maximum is 350 feet. With this much greater thickness, however, there are found only six beds, the same number that occur in western Pennsylvania. In these six beds of the Lower Coal Measures are stored up all the valuable fuel found in what is generally known as the Great Kanawha coal field. This field stretches along the Kanawha river from Charleston to the mouth of Gauley river, a distance of 40 miles, following the course of the stream. The highest bed of coal in the group rises above water level at Charleston, and at Gauley river the lowest one just overshoots the mountain tops.

It must not be supposed, however, that all of these six beds furnish valuable coal along this entire distance. A prominent characteristic of all the six beds of XIII. in the Kanawha valley is their variableness both in thickness and quality. A certain bed may prove excellent on one property, and on the adjoining land thin away to a streak, be split up with partings, or disappear entirely; and as this may happen to every one of the six beds, it results that seldom more than two are workable on the same property, and sometimes none.

These irregularities are referred by Professor White to the rapid subsidence and deposition of sediment, by which 1,100 feet of rocks accumulated there in the same time that 250 to 300 feet accumulated in Ohio and Pennsylvania. This accounts satisfactorily for all such phenomena as the splitting of coal beds by shale and rock deposits; their thinning away and disappearance over wide areas; the fact that only one or two good beds are found in the same hill; and all other features by which this region differs from other coal fields of the country.

The highest member of the No. XIII. coals, called the Lower Cannelton by Professor White, but corresponding in every respect to the Upper Freeport coal of Pennsylvania, rises above the Kanawha river near the Charleston ferry, where it has a thickness of 3 to 4 feet, including parting slates, and is in structure about half way between cannel and ordinary bituminous coal. It seems to contain rather too much sulphur, and hence is not mined except for local use at a few points, though it formerly furnished a considerable quantity of fuel to the salt furnaces between Charleston and Malden. About 4 miles above Charleston it thins away to only a few inches of worthless stuff, and is found no more in workable condition until Coalburgh is reached, 19 miles above Charleston, where two benches of coal are found, separated by 25 to 40 feet of rocks. The lower bench is 3 to 4 feet thick and has long been called the "Lewiston seam," under the mistaken idea that it was the same bed as that once mined extensively at Lewiston or Winifrede junction, on each side of Field's creek. The upper bench is 2¼ feet thick at North Coalburgh, according to Mr. C. C. Lewis, but neither it nor the lower one has been mined in that vicinity, the lower bench being too impure and the upper too thin. At the Crown Hill mines, below Paint creek, the upper bench seems to have thinned away, and the lower one has developed into an excellent quality of "splint" coal, 3 to 4 feet thick. In the river bluff below the mouth of Hughes creek this bed attains a thickness of 5½ feet, the most of which appears to be good splint; but further up the Kanawha it gains quantity at the expense of quality, and in the vicinity of Upper creek it attains a thickness of 11 feet, but the little good coal is so interstratified with worthless stuff as to be valueless. At Cannelton, 2 miles above where it shows such a remarkable thickness, it undergoes another great change, the lower half being developed into 1½ to 4 feet of most excellent cannel, while 2 feet to 2½ feet of bituminous coal rests immediately on top of the latter. The coal has long been mined here, and has received its local designation of "Stockton cannel," from the former owner of this property.

Further up the Kanawha from Cannelton this coal thins away again to a thin bed, and is mined no more, though its outcrop does not pass into the air until beyond Mount Carbon.

The next coal bed below the one last described is known in the Kanawha valley as the Coalburgh seam, from its development at the village of that name, 19 miles above Charleston, but corresponds stratigraphically to the Lower Freeport coal of Pennsylvania and Ohio. This bed is always double, and sometimes triple. Where it first rises above the Chesapeake and Ohio railway, one-fourth mile south from Porter branch, it is split into two or three worthless layers by 25 to 30 feet of sandstones and shales, and these partings do not thin out and bring the separate layers of coal close enough together to warrant mining until in the neighborhood of the Daniel Boone salt works, 3½ miles above Charleston. Here this coal is mined in three benches, each 12 to 24 inches thick, and separated by rock layers of 2 to 24 inches thickness. The coal is known as the "Brooks vein," and is mined for use at the salt furnace. Passing up the river from the Boone salt works the coal again becomes worthless along the river hills by the great thickening of its partings, but at the Snow Hill salt works the partings have thinned away to a small thickness and the bed is again workable. This same productive belt seems to stretch through to the first branch of Campbell creek, along a tributary of which this coal has very much the same structure as seen at the Snow Hill and Boone mines. From this point on up the Kanawha, however, the bed splits up and is worthless until Coalburgh, the region of its greatest development, is reached. Here it has been successfully mined for a long time on both sides of the river, and is characterized by the following structure from above downward:

Splint coal	½ foot to ⅚ foot.
"Nigger head"	⅓ foot to ⅔ foot.
Splint coal	2½ feet to 3½ feet.
Shale	1 foot to 8 feet.
Soft coal	1 foot to 1½ feet.

"The term 'Nigger head,'" says Professor White, "is used by the Kanawha miners to designate a hard, heavy, impure coal, often resembling cannel, which to the unpracticed eye can scarcely be distinguished from genuine coal, but which on the fire refuses to burn up, and remains as a solid block after its carbon has disappeared. It evidently owes its origin to an invasion of the old coal marsh by sediment (fine sand and clay). The Kanawha coals are much injured in value by this substance, since it occurs to a greater or less extent in the upper three beds of No. XIII., and its removal is necessary, however troublesome or expensive it may be. The great heaps of refuse about Coalburgh and other mines along the Kanawha are composed largely of this material."

The Coalburgh bed continues up the Kanawha river from Coalburgh in rather fair development, with only occasional barren patches, until within 2 or 3 miles of Cannelton, when it again deteriorates and becomes worthless, although exhibiting a thickness of 5 to 6 feet on the Cannelton Coal Company's property. Its outcrop passes into the air near the mouth of Loup creek, but the coal has there thinned away almost entirely.

The third important coal horizon of the Lower Coal Measures is locally called the Winifrede bed, being very extensively mined near Winifrede, on Field's creek, a tributary of the Kanawha, 13 miles above Charleston. Its stratigraphical position corresponds to the horizon of the Upper Kittanning coal of Pennsylvania, and the coal is usually a mixture of "splint" coal layers interstratified with richly bituminous ones, the whole making a domestic fuel of excellent quality.

The Upper Kittanning or Winifrede bed first makes its appearance along the Kanawha at the mouth of Wilson run, 2½ miles above Charleston, where it is 45 feet above the river and only 18 to 20 inches thick. It has long since been abandoned in this vicinity, however, on account of its thinness and large amount of impurities, and it really does not attain workable dimensions until in the vicinity of Field's creek. A short distance above this stream it is now mined on the north bank of the river, where it is a most excellent coal. Above this point, however, the coal thins down, and is not of workable thickness or quality until in the region of Upper and Morris creeks, where it comes in again about where the Upper and Lower Freeport beds have become worthless. This is the bed at the Kanawha Mining Company's works, from which the Chesapeake and Ohio railway engines receive their supplies. At Coal Valley, however, 1 mile above the latter locality, the bed has all disappeared except 15 to 20 inches of worthless matter which remains at its proper horizon, and it does not thicken up again to a workable condition before the horizon passes into the air above Loup creek.

The Middle Kittanning coal is represented on the Kanawha by a small but very pure bed of splint coal of sufficient thickness for mining only between Simmons and Kelley creeks. It is extensively mined in the vicinity of Cedar Grove, 1 mile below Kelley creek, and has received its local name from that village. The main coal is free from slate or partings of any kind, but only 2 feet 8 inches to 3 feet 4 inches thick. It furnishes a splint coal of very good quality, though it is difficult to mine, since the only soft coal in it is a few inches at its very top. This coal first rises above the bed of the Kanawha river about one-half mile below Campbell creek, and at the mouth of this stream was once mined to a small extent. In the vicinity of Simmons creek it develops into a workable bed, having a thickness of 40 inches of pure splint, but seems to disappear almost entirely in the vicinity of Cannelton and northward.

The next coal bed, in descending order, is one that has long been successfully mined on Campbell creek, in the vicinity of Malden, and it is generally known in the Kanawha valley as the Campbell Creek bed. In stratigraphical features and persistence it seems to accord well with the Lower Kittanning coal of the Pennsylvania column, and may be considered as identical with that bed. In the Campbell Creek region this bed is from 4 to 6 feet in thickness, and is usually subdivided into three benches by two slates. Passing up the Kanawha beyond Malden, however, these slates begin to thicken and others make their appearance until the upper and lower members of the bed are separated by 20 feet of shales, in which a third layer of coal is generally found. This remarkable expansion of the bed continues until, in the vicinity of the Peerless Coal Company's mine, 10 miles above Campbell creek, the bed is actually 97 feet in thickness, and contains eight or nine layers of coal alternated with shales. But one layer of coal is mined by the Peerless Coal Company in this 97 feet of rock. It is about 2½ feet in thickness, and is a very superior gas coal. Going on south to the Coal Valley region, these rock intervals which separate the members of the coal so widely at the Peerless mine have thinned almost completely away, and on Morris creek the several components come practically together again and form a bed 10 feet thick.

The lower half of the Campbell Creek bed remains worthless until Blacksburg is reached, when the separated members fuse together and form a bed of good coal 4 feet thick. This is often called the Blacksburg coal, but it is only the lower half of the Campbell Creek bed, or that portion of this bed which lies below the Peerless member.

The Coal Valley gas coal is mined from this bed, which also is worked at Ansted by the Hawk's Nest Coal Company, and at the head of Cabin creek.

The lowest coal bed of formation XIII. corresponds stratigraphically to the Clarion coal of Pennsylvania, and has been extensively developed at the Eagle mines, 2 miles above Cannelton, where it has proved a superior coking coal, and hence is generally known along the valley as the "Eagle seam." It is also successfully mined at Frederick, the next station below Eagle.

The productive coals of formation XII. are three in number. The Nuttall coal is the first workable coal bed found in descending from the top of XII. on New river. It has been mined successfully for several years at Nuttall station, on the Chesapeake and Ohio railway, and the coal is designated from that locality. For regularity and persistence this bed seems to surpass any of the coals of formation XIII., since it is never absent at its proper horizon after arising above New river, a short distance beyond Hawk's Nest station. It is there, however, but 2 to 2½ feet thick, and has been mined to only a small extent. This bed increases regularly in thickness toward the south, and at Stone Cliff has attained a thickness of 4½ to 5 feet. It occurs a few feet above the top of the great cliff rock, on the road leading from Prince station to Raleigh court-house, where it is 5 to 6 feet thick, and trends away toward the Flat Top region in a seemingly persistent bed. It is everywhere pure and free from admixture of slate, and is a good coal.

In the vicinity of Sewell station two more workable coals make their appearance in the No. XII. series, the upper one coming about 300 feet under the Nuttall bed, and the other 100 to 130 feet lower. Both have been mined at Sewell, where they are each 3 to 4 feet thick, though quite irregular, the upper one thinning away entirely when followed into the mountain. One of these beds has been extensively mined at Quinnimont and the other at Fire creek, and they have been designated from these localities. The two beds are never well developed at the same time, however, and hence some doubt yet remains as to their relative positions, some coal operators contending that the "Quinnimont bed" is the lower, and others that the "Fire Creek" is. Both are coking coals of excellent quality, though neither can compare with the Nuttall bed in regularity or freedom from impurities.

Of coal fields in Virginia exclusively, the Richmond field is perhaps the most important. The extent of this field is a little over 150 square miles, its shape being an irregular parallelogram, with the northern extremity ending in a sharp point. The geological horizon in which the coal is found is the Jura-Triassic, the mineral occurring there being newer, geologically, than that of other parts of Virginia and West Virginia. The mines, however, have been worked from a very early date. At present there are some half dozen companies developing the field, one of which was recently reported as producing about 300 tons per day. The mine from which this coal is taken is a slope about 2,300 feet long, driven on the coal from the outcrop to a vertical depth of a little over 800 feet. A good development of coal of a general thickness of 25 feet is shown, of extent sufficient to last for many years. Another basin, owned by the Midlothian Company, is said to contain coal over 100 feet thick, free from slate bands and bone, and of exceptional purity.

There are also in Virginia numerous patches of anthracite and semi-anthracite coal, the united area of which is stated by Maj. Jed. Hotchkiss, in *The Virginias*, to be about 100 square miles.

In recapitulating the coal output of West Virginia one must include the coal shipped by the Kanawha river, that by the Chesapeake and Ohio railway, the gas coal on the line of the Baltimore and Ohio railroad, and the bituminous coal sent out from the Elk Garden basin. Its statistics are as follows:

Production of coal in West Virginia since 1873.

Years.	Long tons.	Years.	Long tons.
1873	600,000	1879	1,250,000
1874	1,000,000	1880	1,400,000
1875	1,000,000	1881	1,500,000
1876	800,000	1882	2,000,000
1877	1,000,000	1883	2,085,565
1878	1,000,000	1884	3,000,000

The following figures give the estimated output of Virginia for several years in the past. The statistics for 1869 are those of the ninth census. The very considerable increase shown for the year 1883 is due to the opening of the Flat Top-New River coal field, in the vicinity of Pocahontas, Tazewell county.

Production of coal in Virginia for 1869 *and since* 1880.

Years.	Long tons.	Years.	Long tons.
1869	61,803	1882	100,000
1880	100,000	1883	225,000
1881	100,000	1884	300,000

WASHINGTON.

The coal fields of Washington are the most important of the Pacific coast. Their development may be said to have only commenced, but already their product is much greater than that of any other district on the coast, and promises to increase even more rapidly in the future than it has done hitherto.

Mr. Bailey Willis, of the late Northern Transcontinental Survey, in a forthcoming report on the coals of this Territory, groups them under three heads: (1) "lignites"—those which do not coke, which slack on exposure to the air, contain a considerable percentage of moisture, and are of homogeneous or woody structure, with conchoidal fracture and with a brown streak and a resinous luster; (2) "bituminous lignites"—those which coke slightly, do not air-slack, have a homogeneous structure and irregular, slightly conchoidal fracture, contain but little moisture, but in the ratio of volatile hydrocarbons to fixed carbon and in streak and luster resemble lignites; (3) "bituminous coals," which coke strongly, have a black streak and a more or less cubical fracture, and resemble the eastern coking coals, such as the Kanawha splint, but softer. These three types grade into each other. There are, besides, occurrences of anthracite in the immediate neighborhood of volcanic dikes, not of economic importance. The coals of the Bellingham Bay, New Castle and Renton, and Chehalis Valley fields are lignites, those of the Green River field are bituminous lignites, and those of the Skagit River and Wilkeson fields are bituminous.

The coal deposits of Washington are mainly in the vicinity of Seattle, King county, on the eastern shore of Puget sound, and at Bellingham bay, close to the British Columbia line. The Seattle field is one of the most important on the coast, covering a large area, and its deposits are being developed at several mines, which are steadily increasing in output.

The Bellingham Bay mine, the oldest source of supply on the American side of Puget sound, was first worked upwards of twenty years ago. Its production reached the highest point in 1869, when it sent upwards of 20,000 tons to San Francisco. The shipments to that point in 1871, 1873, and 1876 were also about 20,000 tons. A few years ago the mine caught fire, and though the fire was subdued, it has been worked with little activity since, the shipments to San Francisco having ceased in 1878. The following is an analysis of Bellingham Bay coal:

	Per cent.
Water	8.39
Volatile matter	33.26
Fixed carbon	45.69
Ash	12.66
	100.00

Another important deposit of the Puget Sound region is the coal field lying back of its eastern shores, up against the base of the Cascade mountains. Its width is from 10 to 20 miles, and its length when fully explored will probably be found to be as great as that of the sound itself, reaching from Carbonado northward to and beyond the British Columbia line, a distance of over 100 miles. Mining operations in this field are facilitated by railroad transportation to tidewater.

The Carbon Hill coal mine is about 3 miles from Wilkeson and 32½ miles northeast from Tacoma, near the line of the Northern Pacific railroad. The mine is the largest on the coast, and belongs to the managers of the Central Pacific Railroad Company (Pacific Improvement Company), who have a line of steam colliers carrying the coal to San Francisco bay, for the use of steamers and locomotives of the Central Pacific and Southern Pacific railroads. It is stated that the mine can produce 20,000 tons a month, although in 1884 its production was only about half this quantity. At this mine 234 men are employed, of whom 45 are Chinese. The Chinese are paid $1.25 per day and white men from $2.75 to $3 per day, all boarding themselves. Some work by the piece, and earn from $2 to $3 per cubic yard broken out. These average $2.75 per day. Extensive wharves and bunkers have been built, and the mine has been opened up on a large scale. The coal from this region is a true bituminous coal, hard, solid, black, and clean, not equal in heat-producing capacity to the best Pittsburgh coal, but a good fuel for railroad and steamship purposes.

Back of Seattle, and reached by a narrow-gauge railroad, lies the New Castle lignite field. The coal is of a younger formation than that of the Carbonado district. It comes out in fine, clean, solid blocks, does not slack easily, like the brown coal of Dakota, and has about two-thirds the heat-producing quality of bituminous coal. The New Castle mine, which shipped about 150,000 tons last year, will increase the shipments to 200,000 tons for 1885. This mine is 20 miles from the sea.

The Renton mine is 13 miles east of Seattle, and is producing regularly. Its coal is sent to the seaboard by the Columbia and Puget Sound railroad.

WYOMING.

The coal fields of Wyoming are of great extent and value. They have been known since 1850, but remained undeveloped until the completion of the Union Pacific railroad to Carbon, 100 miles west of Laramie, in 1868. The Coal Measures are estimated to cover at least 20,000 square miles of the surface of Wyoming, and the beds are found for nearly 350 miles along the line of the Union Pacific, in every case where developed cropping boldly on the surface. In quality the coal is a lignite of superior grade, and suitable for all heating and domestic purposes, but non-coking and useless for gas making.

The vein which is worked at Carbon is 9 feet in width, the coal being the best quality of Tertiary brown coal—compact, pure, and comparatively free from moisture. It is used almost entirely as fuel on the Union Pacific railroad, the supply of coal for domestic purposes coming chiefly from the mines at Rock Spring. The following analyses were made of specimens taken from two veins at Carbon:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Water	8.10	6.10
Volatile matter	34.70	38.80
Fixed carbon	51.65	49.30
Ash	5.55	5.80
	100.00	100.00

The mines at this point were first opened in 1868, and have been worked steadily since that time. The following table gives the output of the district since 1868:

Product of the Carbon mines, Wyoming.

Years.	Short tons.	Years.	Short tons.
1868	6,560	1877	74,343
1869	30,482	1878	62,418
1870	54,915	1879	75,424
1871	31,748	1880	100,433
1872	59,237	1881	156,820
1873	61,164	1882	200,123
1874	55,880	1883	248,380
1875	61,750	1884	319,883
1876	69,060		

On the line of the Union Pacific railroad from Bitter Creek to Rock Spring coal mines are opened for almost the entire distance. In some cases work has been discontinued, but the output is included in the general summary.

The coal at Rock Spring is generally conceded to be one of the best bituminous lignites found in the Far West. Its remarkably low percentage of ash and freedom from water and sulphur make it a favorite coal wherever it can be obtained. It is in general use throughout the towns in Wyoming, and large quantities of it are burned in Denver, Salt Lake City, and Ogden. It is a jet-black, semi-bituminous coal, producing no clinkers, and leaving but a small bulk of ash, which is of a reddish color. Its composition and value are shown by the following analysis:

	Per cent.
Water	7.00
Volatile matter	36.81
Fixed carbon	54.46
Ash	1.73
	100.00

It is a clean-breaking coal, which does not slack upon exposure to the influence of the atmosphere. The mine was opened in 1868 by Mr. Thomas Wardwell, who was in the employ of the Union Pacific Railroad Company, which is the present owner of the mines. The product of the district since 1868 has been:

Product of the Rock Spring mines, Wyoming.

Years.	Short tons.	Years.	Short tons.
1868	365	1877	146, 494
1869	16, 933	1878	154, 282
1870	20, 945	1879	193, 252
1871	40, 566	1880	244, 460
1872	34, 677	1881	270, 425
1873	44, 700	1882	287, 510
1874	58, 476	1883	304, 495
1875	104, 664	1884	318, 197
1876	134, 952		

The mines at Almy, on the line of the Union Pacific, are owned by the Union and Central Pacific Railway Companies. The coal is much inferior to that found at Rock Spring, but is used in large quantities by the railways for their locomotives. The composition of the coal is shown by the following analysis:

	Per cent.
Water	15. 40
Volatile matter	33. 90
Fixed carbon	44. 78
Ash	5. 92
	100. 00

The mines were opened in 1869, and have produced large quantities of coal. In 1872 the Rocky Mountain Coal Company, at Almy, produced 105,060 tons of coal, and during the same year the Union Pacific mines produced 22,713 net tons. Since 1875 the Rocky Mountain Coal Company has come, by lease and purchase, into the possession of the Central Pacific Railroad Company, which now operates it. The product of the Union Pacific mines has been as follows:

Product of the Union Pacific mines at Almy, Wyoming.

Years.	Short tons.	Years.	Short tons.
1869	1, 967	1877	54, 643
1870	12, 454	1878	59, 096
1871	21, 171	1879	71, 576
1872	22, 713	1880	100, 234
1873	22, 847	1881	110, 157
1874	23, 006	1882	117, 211
1875	41, 805	1883	111, 713
1876	60, 756	1884	150, 880

At Almy the mines owned by the Central Pacific Railroad Company, from 1870 to 1884, inclusive, produced the following amounts:

Product of the Central Pacific mines at Almy, Wyoming.

Years.	Short tons.	Years.	Short tons.
1870	16, 981	1878	57, 404
1871	53, 843	1879	60, 739
1872	05, 118	1880	82, 684
1873	130, 989	1881	90, 779
1874	181, 699	1882	94, 065
1875	92, 589	1883	78, 450
1876	69, 782	1884	68, 471
1877	67, 373		

The only other district in which coal mining is actively pursued is at Twin creek, on the Oregon Short Line railroad. The coal here is an excellent, soft, non-slacking coal, suitable for many uses. Near the Twin Creek mine a cropping of coal shows twenty-nine beds, which vary in width from 1½ to 48 feet. The mine was opened in 1875 by the Wyoming Coal and Coke Company, but little was done in the way of systematic development and a regular production until its sale to the Union Pacific Railroad Company in 1881. The composition of the coal is shown by the following analysis:

	Per cent.
Water	8. 58
Volatile matter	35. 22
Fixed carbon	49. 90
Ash	6. 30
	100. 00

The product of the mines here has been:

Years.	Short tons.
1882	8, 855
1883	36, 651
1884	45, 189

Coal has been mined with varying success at many other points along the line of the Union Pacific, and by independent companies, but work upon the mines has been stopped until increasing demand or the exhaustion of some of the beds at present worked necessitates the development of new fields. The entire coal fields of Wyoming are practically controlled by the Union Pacific Railroad. The capacity of these beds is indefinite. They would be able to supply at any time the whole demand of the Far West with a uniformly good coal. Coal has been mined in former years at Separation, Point of Rocks, Black Buttes, Old Rock Spring, Bear river, and other points, but present production is limited to the localities described. Prior to 1871, at Separation, Point of Rocks, Black Buttes, Old Rock Spring, and Bear river, it is estimated that over 100,000 tons of coal were produced, but the annual product is not obtainable. The product of the Territory for the years from 1868 to 1884, inclusive, has been as follows:

Recapitulation of the coal production of Wyoming since 1868.

Years.	Carbon.	Rock. Spring.	Almy.		Twin creek.	Total.
			Union Pacific mines.	Central Pacific mines.		
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
1868	6, 560	365				6, 925
1869	30, 482	16, 933	1, 967			49, 382
1870	54, 915	20, 945	12, 454	16, 981		105, 295
1871	31, 748	40, 566	21, 171	53, 843		147, 328
1872	59, 237	34, 677	22, 713	105, 118		221, 745
1873	61, 164	44, 700	22, 847	130, 989		259, 700
1874	55, 880	58, 476	23, 006	81, 699		219, 061
1875	61, 750	104, 664	41, 805	92, 589		300, 808
1876	69, 060	134, 952	60, 756	69, 782		334, 550
1877	74, 343	146, 494	54, 643	67, 373		342, 853
1878	62, 418	154, 282	59, 096	57, 404		333, 200
1879	75, 424	193, 252	71, 576	60, 739		400, 991
1880	100, 433	244, 460	100, 234	82, 684		527, 811
1881	156, 820	270, 425	110, 157	90, 779		628, 181
1882	200, 123	287, 510	117, 211	94, 065	8, 855	707, 764
1883	248, 380	304, 495	111, 713	78, 450	36, 651	779, 689
1884	319, 883	318, 197	150, 880	68, 471	45, 189	902, 620

The number of men at present employed in the mines of the Territory is about 1,000. The wages paid range from 90 cents to $1.15 per ton.

ANTHRACITE COAL MINING.

By H. M. Chance.

In preparing this paper an effort has been made to present as concisely as possible the chief features of anthracite mining methods in Pennsylvania in such a manner that miners in other regions may be enabled to compare these systems with their own. The details of construction and operation, and the minor variations in mining methods found throughout the region, are not here discussed. For such fuller information reference may be had to Report AC of the Second Geological Survey of Pennsylvania, on the "Mining Methods and Appliances used in the Anthracite Coal Fields," by the present writer.

The mining of anthracite coal in Pennsylvania dates from 1820, when 365 tons were shipped from the Lehigh region to Philadelphia. The first coal there mined was worked by an open cut at Summit Hill. A few years later (1822–'25) the Schuylkill region was opened to market by the Schuylkill Navigation Company, and in 1829 mining was commenced in the Wyoming region, with a shipment of about 7,000 tons. The wonderfully rapid growth of this industry has effected great changes in the mining methods and in the mechanical appliances used both in mining and preparing the coal for market—changes necessitated for the most part by increased depth, with enormous volumes of water to be handled, great and constantly increasing volumes of firedamp to contend with, and the enlarged output of the collieries of to-day as compared with that of earlier operations. For the first twenty years following the opening up of these coal fields mining was confined principally to coal lying above water level, which could be reached by tunnels and drifts. These mines were self-draining, and they commonly enjoyed another advantage over the mines of to-day, namely, the absence of large quantities of firedamp, this gas rarely existing in great volume above water level.

Location and structure.—The anthracite coal fields of Pennsylvania lie entirely east of a north and south line drawn through Harrisburg, and north of the Blue ridge or North mountain. They consist of a number of long, narrow basins, roughly parallel to each other and with a southeast and southwest trend. These basins are generally canoe-shaped troughs, the coal dipping in towards the center from the northern and southern edges; but the north dips are steeper than the south dips. Thus, in the Southern, First, or Pottsville basin the south dip (on the north side of the basin) ranges from 5° or 10° to 40° or 54°, while the north dip (on the south side of the basin) is commonly from 60° to vertical. The large basins are divided into a number of sub-basins by a more or less complicated series of minor anticlinal and synclinal folds, which warp the coal into curiously curved surfaces, with dips ranging all the way from vertical to horizontal. Some of these flexures are overturned, and in places the coals are found folded back, with a reverse dip. Sharp breaks or changes in the dip are not common. The coals generally curve gently from a steep to a flat dip or *vice versâ*, and it is to this feature that the practice of mining by slopes owes its great success.

Pennsylvania anthracite is almost unique as a domestic fuel. It is extremely hard, somewhat brittle, and contains a very small percentage of volatile matter. Hence to burn such a fuel successfully in stoves or grates it is absolutely necessary to have a uniform draught, and this can only be accomplished by thorough separation of the coal into grades of uniform size. As the coal beds frequently contain seams of slate, and as it is often impossible to separate this from the coal in mining, the process of preparation includes the separation of slate and other refuse. The building in which this is done is known as the "breaker," and constitutes the most striking portion of an anthracite colliery plant at the surface.

Mining plant.—The plant at the surface comprises:

1. The breaker.
2. Engine for driving the breaker machinery.
3. Boilers and coal bins, feed-water pumps, etc.
4. Winding engines, etc.
5. Head frame.

6. Pumping engine.
7. Ventilating fan.
8. Culm or dirt or waste and rock banks, with inclined plane.

In the arrangement of the plant aboveground no one system has been generally adopted by mining engineers throughout the anthracite region. The arrangement is necessarily varied to suit the topography of the ground, and alterations are constantly being made to meet the requirements of increased output, with increased depth and extent of workings. The best practice seems to be that in which all the steam machinery is housed in one building, and the breaker operated by wire-rope transmission of power from this building; the boilers placed together under a separate shelter; the head frame built open (unhoused), and the breaker located some distance from the shaft. A plan in favor some years ago was to build the breaker directly over the shaft, and to place the breaker engine, and sometimes the hoisting engine also, in the same or an adjoining structure, but the risk from fire and of seriously complicated mine accidents is so great that this plan has been discarded.

Prospecting.—Anthracite properties can generally be prospected for shallow workings by shafts sunk by hand; but when the exact position and thickness of the coals at considerable depth must be known, resort is had to boring. There can be no doubt that for this work the diamond drill has given the best and most satisfactory results. Where the depth only of a coal is to be determined, a hole drilled by the rope-drilling method, as used in the oil regions, gives equally good results, and often at from one-half to one-fourth the cost of a diamond-drill hole. The cost of drilling with the diamond drill increases so rapidly with the depth that holes are seldom sunk by this method more than 800 to 1,200 feet in depth. This objection does not apply to the rope-drilling method.

The best method of constructing geological cross-sections has become of considerable importance to mining engineers. The limits of this article forbid a discussion of this subject. Reference may be had to Report AC of the Second Geological Survey of Pennsylvania.

Methods of opening coal.—The geological structure always determines the method to be adopted in opening a coal bed. When the outcrop is accessible and the coal dips more than 10°, it is considered best to develop by slopes driven down upon the bed, following the dip of the coal from the surface down. Beds lying above or below the main seam are frequently developed by driving tunnels (cross-cuts) through the intervening rock from each gangway in the main workings. When the coal is to be opened by shaft, the shaft is located in the deepest part of the basin, or in the deepest part on the property to be developed.

The mines ventilation act requires each mine to have two outlets. Unless the property contains a swamp or small basin, or parts of two basins, the location of this second opening is not a matter of much importance; but if such be the case, then this shaft is best located in the second basin or trough.

Lift mining.—In developing by slope the usual practice is to sink the slope and its airway side by side (parallel), but with a sufficiently thick pillar between them. At a depth of about 100 yards a "lift" is opened out by driving a gangway both to the right and left. The breasts opened along these two gangways constitute the "first lift." This is often worked for several years before the slope is sunk to open a second lift, but it is now common to continue the sinking without waiting until the coal on the upper level is exhausted. This work is prosecuted at night, so that the mining and hoisting of coal is not interfered with.

The "second lift" is usually opened out at a depth (on the slope) of 75 to 90 yards below the first lift. Sometimes three or four lifts are opened at once, but there are few collieries mining coal from more than three lifts at once, although many of them have exhausted two, three, or even four lifts, and are now working in the fifth, sixth, and seventh lifts.

Drainage.—In "lift mining" the water is caught on each gangway when this is possible, and at many collieries nearly all the water is caught on the first and second lifts, and the lower workings are very dry; but as the workings are extended from year to year it is generally found more expensive to attempt to hold this water up than to pump it from the lower workings, for to do this thick chain pillars must be left below each gangway and long lengths of gangway through exhausted ground must be kept open. Hence mining engineers are now generally abandoning this practice, and make no effort to hold the water except perhaps on the "water-level" (self-draining) gangway. By the adoption of this plan a much larger percentage of coal is recovered, as the chain pillars and breast pillars are robbed as soon as the gangway is worked out, and the gangway is then abandoned.

When the outcrops of the coals cross swampy land or flat valleys, large expenditures are sometimes incurred by the necessity of deflecting the stream or of carrying it over the outcrops in a flume. This must be done as soon as the workings approach the surface, and many instances might be cited of disastrous mine floodings that might have been averted in this way.

When the workings are approaching old workings suspected to contain inflammable gases or to be inundated with water, the law requires boreholes to be constantly kept 20 feet in advance of the face of each and every such place, and if necessary on both sides.

In lift mining the sump is commonly excavated in the coal beneath the gangway level. Where the water is caught on each lift, a sump or lodgment is of course provided on each gangway. The water is conveyed to the sumps along drains or gutters cut on one side of the gangway, more rarely in the center under the track; and these gutters have of course the same fall as the gangway, which is most commonly about 1 foot in 200 feet.

In the deep-shaft collieries, where the coal lies on gentle angles of dip, as at Pottsville, Wilkes-Barre, etc., the quantity of water to be pumped from the lower levels is very small as compared with that found in contorted and steeply dipping coals, as of the Panther Creek and Hazleton districts. The former are known as "dry mines," some being so dry that coal dust accumulates in enormous quantities in the rooms and passages. At many of the wet mines of the Lehigh district an average of from 8 to 10 tons of water is pumped from the mine for every ton of coal raised, and at a few collieries more than 20 tons has been pumped for every ton of coal raised; but in the dry mines of the deeper parts of the Schuylkill and Wyoming districts the water tonnage is often less than the coal tonnage. However, even under such circumstances pumps of no small capacity are needed.

The rod-plunger pumps of Cornish pit-work style, run by high-pressure, horizontal, flywheel engines, bull pumps, and inside steam pumps are used, almost to the exclusion of other forms. The average working speed of the bull pumps is four to five strokes, running up to seven or eight strokes per minute in emergencies. Rod-plunger pumps, driven by geared, high-pressure, horizontal engines, run at a higher average speed, say five to seven strokes. The old-style Cornish walking-beam engine is not used in the anthracite region. Nearly every style of steam pump made in this country has been used in these coal fields, but the plunger pumps have almost entirely displaced piston pumps. The strongly acid water quickly ruins ordinary piston pumps. Exhaust steam underground and heat from the exhaust are objections almost fatal to the use of steam pumps in the mine, as the heat and moisture hasten the decay of mine timber so that it is destroyed at a ruinously rapid rate, and they also frequently soften the roof or floor, and thus bring greater strains upon the already weakened timbers. The exhaust is sometimes conveyed to the surface, sometimes thrown into the sump, and sometimes into the upcast; but, with rare exceptions, it is, however disposed of, an unmitigated nuisance and costly evil. Compressed air has recently been introduced at several collieries to run underground pumps and hoisting engines. It apparently costs but little more than steam (barring first outlay) and is open to none of its objections.

A few collieries are not provided with pumping machinery; the quantity of water being quite small, it is raised in tanks or tank cars.

Shafts.—Anthracite mining shafts are nearly always of rectangular cross-section. Their width is governed by the length of the mine cars, which range from 9 to 10½ feet over all, and the shafts are therefore commonly 10 or 11 to 13 feet wide inside the timbers. The (horizontal) length of the shaft is governed by the number of compartments needed for hoisting and the cross-sectional area required for an airway. Each compartment is made 6 or 8 feet broad inside the buntons, or, on an average, about 6½ feet between the guides; hence the compartments measure 7 to 9 feet from center to center. A shaft with two compartments is therefore given a length of 16 to 20 feet; with four compartments a length of 30 to 38 feet is required. In addition to the space devoted to these hoistingways, a large space is necessary for an airway, so that the (horizontal) length of shafts recently sunk often greatly exceeds the above figures. Thus the Dorrance shaft of the Lehigh Valley Coal Company is 13 feet by 52 feet; the Woodward shaft of the Delaware, Lackawanna and Western Coal Company is 10 feet by 53 feet; and the Gaylord shaft is 12 feet by 47 feet.

That very few shafts have been sunk with power drills is doubtless owing to the character of the slates, shales, and sandstones passed through being such that good time can be made by hand drilling; and it is not at all certain that the speed can be increased and the cost decreased by the use of steam or compressed-air drills. The first cost of the compressors and drills, for which there is commonly no use afterwards, is probably the true reason why these drills have not come into more general use.

Explosives of the dynamite type are used very largely i[illegible]work of this character, and simultaneous firing of groups of holes by electricity is the plan now preferred, as giving the best results at the least expenditure of time and powder.

When the sinking passes through drift or alluvium (sand, clay, gravel) carrying water, before striking bed rock a water-tight cribbing or curbing is built to shut this water out. This is built double, like a coffer dam, and is packed with clay.

At most shaft collieries two compartments are sufficient to handle the coal; but with large outputs a third compartment is devoted exclusively to raising and lowering men and supplies, so that the work of raising coal shall not be interrupted. The compartments used for hoisting are utilized for ventilation as a downcast airway, and another compartment of sufficient size is bratticed off for the upcast, and this is also used for the pumps and column pipe and as a manway. Where the second opening (shaft or otherwise) is used as an upcast and the whole of the main shaft is used as a downcast, it is still necessary to provide a separate compartment for the pump rods and column pipe. Instead of providing a separate compartment in the main shaft for raising and lowering men and supplies, the second opening is sometimes fitted up with winding machinery for this purpose; but if this shaft is also used as an upcast, it must be fitted with double trap doors, a dangerous practice, not approved by mining engineers throughout the region.

Shaft sinking is commonly carried on with a temporary sinking plant consisting of engine and boiler, sinking pump, and head frame. While sinking is progressing, the permanent boilers, winding engines, breaker, etc., are erected, and the permanent head frame may also be put in place without removing the temporary structure, the former being built over the latter, so that no stoppage in the work of sinking and of opening gangways is caused by the erection of these structures.

When the rocks passed through are hard and compact they frequently require no timbering, or the timbering eventually necessary is limited to certain parts of the shaft. Under such circumstances the sinking may be carried down to the coal, and the shaft is then timbered up from the bottom, that is, with such timbering as is needed; but it is of course always necessary to have substantial buntons to carry the guides, the pump rod, column pipe, etc. The bottom of the shaft is sunk some little distance below the coal, to provide a well and a pit for the cages. The sump is excavated in the coal to the dip (below the gangway level), gangways are started right and left, and the work of development is commenced.

From 200 to 300 feet per year may be considered as a fair average of the time made in sinking, including all stoppages. There is little difference in the speed of sinking shafts of large and small cross-sectional area. In sinking through the harder rocks of these Coal Measures the cost ranges from $5 to $8 per cubic yard for shafts 400 to 800 feet deep, the cost increasing rather rapidly with the depth. In shale and soft sandstone and slate the cost is from $2 to $5 per cubic yard.

The long-hole diamond-drill method was used in sinking the Pottsville deep shaft and the Ellengowan shaft, but it does not seem probable that this plan will come into general use. It is doubtless best adapted to shafts 200 or 300 feet deep, where all the holes can be drilled from the surface to the bottom at one operation. The Kind-Chaudron process has not been used in these coal fields.

Slopes.—The main hoisting slope is commonly divided into three compartments, two for hoisting, and one smaller compartment for the pump rods, column pipe, etc., and sometimes a fourth small compartment on the opposite side of the slope is used as a manway, more rarely as an airway. Main hoisting slopes are from 16 to 24 feet wide and about 7 feet high in thick beds; in thin beds somewhat lower. The hoisting compartments are from 6 to 9 feet wide. Sometimes there is only one hoistingway, with three rails and a turnout for the cars to pass each other halfway down the slope; but this is not considered good practice, and inevitably leads to many derailments and collisions.

In slope sinking the timbering is carried down with the sinking. The best form is the completely framed set, with foot-sill and center-props (two or three), with the legs set at a batter of about 1 to 4. Some slopes require no timbering except at the mouth, and others are timbered only with center-props, while in loose coal, shattered by pressure and with a tendency to "run," the timbers are set as close as they can be placed. The foot-sills are notched into the rib (pillar) to hold the timbering in place, and the rails are often spiked directly to the sills and to small sleepers laid between them, and wedged in place by short struts.

Gangways.—The extraordinary thickness of most of the anthracite coal beds enables the mining engineer to drive gangways of almost any desired size or shape. Seven feet in height in the clear and 9 to 12 feet wide are the common dimensions for a single-track gangway, but when the gas is troublesome they are sometimes driven 14 feet wide and 8 feet high. Where double tracks are necessary, as at turnouts and at the landings at the foot of slopes and shafts, the width is 16 to 20 feet or even more. In such cases very heavy timber is needed, and it is frequently necessary to reinforce the caps (collars) by center-props; but center-props are avoided whenever and wherever they can be dispensed with, as they are the cause of many accidents to mules, drivers, and miners. Footsills are rarely necessary in gangway timbering. Round timber is used almost exclusively on gangway work, and the lagging is round or half-round stuff. From 12 to 14 inches may be taken as an average measurement of the timber used (small end), but on turnouts and in loose coal 18- and 20-inch stuff is used. Much 24-inch timber could be used to advantage if it could be obtained, but mine owners experience great difficulty in obtaining stuff of this size at moderate cost. The standard upright form of gangway timbering is commonly framed so that the legs stand on a batter of 1 to 4. In mines using steam underground the timber has a very short life, often rotting in a few months. Some gangways need retimbering every year. Under more favorable conditions timber is now standing, perfectly sound, that was placed fifteen or twenty years ago; but this is the exception, not the rule.

An independent airway is nearly always driven parallel to and a few yards distant from the gangway, and the two passages are connected at intervals by cross-headings. Except in very gaseous workings, this airway is made much smaller than the gangway, about 6 by 8 feet or perhaps a little larger; but in some districts, as at Wilkes-Barre, it is necessary to drive the airways as large as the gangways (8 by 12 feet). The gangway is used as an intake and the airway as the return airway, the air being led up to the face from the last cross-heading by brattice. When the coal bed is thick the airway is driven at a higher level than the gangway, sometimes almost vertically above it, and the coal taken from the airway is then thrown into the last cross-heading, which is used as a chute, and falls by gravity into a car standing on the gangway below. A buggy is used in the airway. When the coal is not gaseous, ventilation is often effected by bratticing off an airway on one side of the gangway. This answers very well during the driving, but is a most unsatisfactory method of securing permanent ventilation, as such brattices always leak badly.

Tunnels.—In tunnel driving an airway is sometimes secured by bratticing off the upper part of the tunnel, but it is more common to brattice off one side. Single-track tunnels are commonly 8 to 11 feet wide and 6 to 8 feet high, unless the gaseous condition of the beds developed by them requires greater cross-sectional area. Double-track tunnels are about 14 feet wide. The cost per cubic yard of tunnel driving varies but slightly from that of shaft sinking, depending of course largely upon the nature of the rocks to be pierced.

Mining systems.—All underground anthracite mines, with perhaps one or two individual exceptions, are operated upon one and the same general system, namely, the "pillar and breast" ("pillar and room," "post and stall," "stoop and room," "board and pillar"); and although the details of this system under different mining conditions vary so widely that the superficial observer sees apparently several totally unlike systems, a careful inspection discloses the fact that they all have three identical characteristics: (1) the "breasts" or "rooms" (working places) are all long and narrow; (2) they are driven nearly parallel to each other; (3) they are separated by long, narrow pillars of coal, broken only by small openings for ventilation. These are the characterizing features of the "pillar and breast" system of mining.

In a few localities where large bodies of coal lie close to the surface the coal is mined by stripping. It is entirely unnecessary to dilate upon this open-cut work. The coal that can be mined in this way is quite insignificant compared with the enormous bodies under deep cover.

The pillar and breast system used in the anthracite regions is simple and elementary in its general features, but its details present a multitude of complicated variations. To describe its general features we may conveniently consider the workings as divisible into two classes: (1) those on beds dipping from about 25° to horizontal, or flat workings, and (2) those on beds dipping from about 25° to vertical, or steep or pitching workings.

In flat workings opened by shafts the gangways are driven off on each side, and when they have reached a sufficient distance to allow a thick pillar of coal to protect the shaft, "breasts" or "rooms" are opened out along the upper side of the gangway. When the dip is less than 5°, a track is laid from the gangway track up into each breast. If the dip is over 3° and less than 7°, the breasts are turned at an angle to the gangway (instead of at right angles), to reduce the grade of the breast roadway. These rooms are either opened out to the full width of 8 to 12 yards on the gangway, or a small opening just large enough to admit a mine car is driven in 8 or 10 yards and the breast is then opened out to its full width. Very flat breasts are sometimes driven long distances, occasionally reaching a length of over 200 yards. It is more common, however, to find a counter-gangway driven across the upper limit of the first row of breasts, which are usually 100 to 150 yards long, and the coal is taken out along this counter-gangway. On steeper dips the mine cars are lowered from this to the main gangway by a self-acting plane built in a worked-out breast. When the coal lying above the shaft is exhausted, that lying at a lower level is frequently opened by an inside slope sunk from the main gangway. A gangway is driven off from the foot of this slope, and the coal is mined in the same way as that on the upper levels.

When the dip is 5° or 6° to 12° the plan of working is the same; but as the mine cars cannot be taken up to the face, the coal is brought down to the gangway in a "buggy," which holds from half a ton to one ton of coal. It is dumped on a platform and loaded into the mine car by hand, but by running the buggy upon a trestle the coal is sometimes dumped directly from the buggy into the mine car. When the inclination exceeds 12° the buggy may be discarded and replaced by a chute lined with sheet iron, or by sheet iron laid on the floor of the breast. The coal must be pushed down over these plates. From this inclination up to 25° the general plan of working is the same, the coal sliding down to a platform near the gangway, where it is loaded into the mine cars.

Sudden changes in the direction and strength of dip often destroy the simplicity of this system of working, by necessitating the driving of many counter-gangways and the addition of planes and slopes to overcome adverse grades and favorable grades of too great pitch.

When the dip exceeds 25° the method of development is principally by slopes, and is known as "lift mining," to which reference has already been made. The breasts are opened by a chute about 6 feet high by 6 to 9 feet wide, and this is driven upon the bed 8 or 10 yards from the gangway before the breast is opened out to its full width. Frequently each breast is opened by two such chutes, which are placed about 15 feet apart. The breasts on each lift are worked up to the gangway above, and when this is worked out they are holed through and the pillars are robbed out.

There is considerable variation in the thickness of pillars both in pitching and flat workings, the range being from 6 to 10 yards. Slope pillars and barrier pillars are 15 to 30 yards thick. Barrier pillars are thick pillars left at intervals of every ten or twenty breasts, or between two sets of workings, or between adjoining properties, to prevent a squeeze caused by the settling down of the superincumbent rocks from becoming general and doing extensive damage; in other words, to localize its effects.

The distance worked on each side of a slope is governed by the cost of haulage and by the cost of keeping open long gangways through exhausted workings. When the coal is hard and the old workings have not been robbed out, it is often found cheaper to haul coal 2, 3, or even 4 miles than to sink a new slope and open new workings; but the limit is generally much smaller, and at a majority of collieries coal is not mined at a greater distance than 1 mile or thereabouts from the main hoisting slope.

When a slope is sunk to the second lift, the first lift is frequently converted into a counter-gangway and the coal is lowered by an inside plane or by a chute to the lower gangway, so that all the hoisting is done from one landing, and the winding machinery is thus rendered more effective in handling a large output.

The working places are termed "breasts," but on flat dips they are more frequently spoken of as "rooms" or "chambers." To describe more clearly the methods of opening, ventilating, and working breasts, they may be conveniently divided thus: (1) wagon breasts, in coal dipping less than 7°; (2) buggy breasts, in coal dipping 6° or 7° to 10° or 12°; (3) chute breasts or pitching breasts, in coal dipping 12° or 15° to 90°.

Wagon breasts.—Rooms into which the mine car is taken directly to the working face are known by this name. They admit of few variations in the method of working. They are opened either to full width on the gangway or by a wagonway driven in 8 or 10 yards before opening out to full width. This plan is adopted when the roof is poor, as it saves timber on the gangway, or when the gas is very troublesome. Breasts of this class are necessarily driven in such a way as to secure a favorable grade for the mine car, and they are consequently often curved, not adhering to a straight line. Their width is, of course, dependent upon the nature of the roof—7 to 10 yards, 8 yards being the most common size. With 8-yard rooms the pillars are 6 or 7 yards; with 10-yard rooms the pillars are 8 yards thick. Ventilation is maintained by cross-headings through the pillars every 15 or 20 yards; these cross-headings are 5 or 6 feet by 6 or 8 feet, except when large quantities of gas demand a larger area. When the bed is thick the bottom bench is sometimes worked out to the limit, and the upper coal is then blown down by commencing at the back end of the breast; but this practice is not general. To reach the top coal the miner stands on a pile of loose coal that is allowed to lie against the face for this purpose. When this is not sufficient, ladders or rough scaffoldings are used. In all breasts of this class the slate and other refuse ("gob") is thrown on one or both sides of the breast.

Buggy breasts.—These are opened and worked in very much the same way as wagon breasts. Whenever possible, the buggy tramway is carried on a staging near the mouth of the breast, so that the buggy may be run out on this and the coal dumped directly into the mine car, thus avoiding double handling of the coal. When this is done the chute or opening of the breast is enlarged enough to make room for a mine car, and a siding is laid in from the gangway track, so that a mine car may stand in this recess, while being loaded, without blocking the gangway. The entrance of the breast can then be closed by a door, thus cutting off all communication with the gangway. The refuse ("gob") is piled on one or both sides of the breast.

Pitching or chute breasts.—When the dip is less than 18° to 22° coal will not slide on sheet iron, and the miner must push the coal down; but on steeper slopes the coal will run readily. On inclinations less than 25° or 30° breasts may be worked like buggy breasts, with one chute, ending in an apron projecting into the gangway high enough to allow a mine car to pass beneath it to be loaded. When the roof is good and the breasts are driven 10 or 12 yards wide, they are opened with two chutes. When the dip exceeds 30° the coal will slide on the floor of the breast without sheet iron; but as the gob will also slide down the pitch and run out with the coal, a different method of working is necessary; and in this case the breast is opened by driving up two chutes 8 or 10 yards and then opening it out to full width. The pillar of coal between these chutes is called a "stump." Each chute is closed by a plank partition, with an opening (drawhole) through which the coal is drawn. As the breast is driven up the dip, the gob is thrown in the center and the coal is thrown down the chutes. These chutes are also used as manways and airways. When the bed is thin they are made by standing a row of props along each side of the breast 4 to 6 feet from the pillar. These are planked if necessary, forming a partition to hold the gob in the center of the breast. If the bed is thick, a "juggler" manway is built. This consists of an inclined partition made by placing inclined props or "jugglers" from the pillar to the floor, thus forming a three-cornered manway or chute. They are notched into the pillar coal and also into the floor to hold them securely in place.

When the coal dips more than 35° or 40° this method of working is not feasible, as the miner has nothing to stand on unless the bed contains so much refuse that the top of the gob left in the breast is always within a few feet of the working face. This rarely happens. When the bed is thin the miner easily builds a platform upon which to stand by placing three or four props across the breast and covering them with plank. This plan is adopted on dips of 35° or more in beds 10 feet thick or less, but when the bed is thick some other method is required.

The two chutes are closed by a strong log battery, with an opening through which to draw the coal, and the whole breast is kept full of coal to furnish a support for the miner. As the broken coal occupies more space than coal in the solid, the miner always has a certain amount of surplus coal. This he sends down the manway, and the other coal lying in the breast ("stock coal") is allowed to remain until the breast is driven to the limit.

When the dip is so steep that the surplus coal falls down the manways with great violence, this surplus coal is sometimes drawn from the breast from time to time through the battery at the bottom. When this plan is to be adopted it is often considered best to open the breast with one central chute instead of two, as the movement of coal in the breast then takes place in the center, and the jugglers on either side are not so likely to become unseated and the manways closed as when there is a drawhole on each side of the breast. Single-chute breasts are also often preferred in gaseous workings, because their connection with the gangway can be more perfectly severed and the ventilation thus rendered more effective.

It will be observed that in working by these latter methods all the bony coal, slate, sulphur, and other impurities are allowed to remain with the coal filling the breast, and that when this coal is drawn out and run into the mine cars this refuse is still in the coal and must be separated from it in process of preparation. At some collieries a loading platform is built in the chute below the drawhole, and as the coal runs out upon this platform the slate is separated from the coal and thrown into a subdivision of the chute, where it lies until a carload of refuse is obtained, when it is loaded into a mine car and sent out to be dumped on the waste or rock piles.

When the bed is not thick enough to carry an independent airway over the gangway, the chutes are driven up until they intersect the heading (airway) and the breast is opened out just above the airway, a battery being built in the heading immediately above each chute, and the air is then coursed through the breast. A manway is sometimes driven up through the center of the stump pillar until it intersects the heading, and this is then used as a traveling way and to take up timber, etc. A modification of this plan is often effected by driving the chutes a few feet above the airway before opening out the breasts to full width. This leaves the airway open. A brattice or door is placed in the airway midway between the two chutes and the air is coursed through the breast; but in case of accident to any breast by closure of the manway, the ventilation of other breasts is restored by opening this door.

To insure good ventilation in single-chute breasts, and reduce the risk of closure to a minimum, a manway is often driven up in the pillar between each pair of breasts, and after being driven up a few yards is forked out to intersect each breast. From the tops of these branches juggler manways are carried up each breast, as in other plans of workings.

When the coal dips steeply the gangway is not infrequently driven in the top bench of coal, against the roof, instead of against the floor, the risk of closure by crushes being much decreased and the excessive pitch of the chutes being reduced by this plan. The cost of working is increased by the increased length of the chutes, manways, and airway cross-cuts.

In single-chute breasts the main chute is not always at the center, but is sometimes on one side of the breast, and a manway chute is driven up on the opposite side to take the manway (surplus) coal and furnish ready access at all times to the workings. On very steep dips the lower end of the chute is slanted or curved to check the descent of coal from the battery and prevent it from jamming fast and blocking the chute. In addition to these methods of working steep pitching breasts, many other plans have been devised, some of which have been tried and abandoned and some are now in use at a few collieries; but the above-described plans cover the essential features of all the methods in general use.

Mining or cutting coal.—The actual mining or "cutting" of bituminous coal is effected by making an undercut with a coal pick in the bottom bench or floor or a slate parting near the bottom of the bed, and then breaking down the coal by wedging, by blasting, or with a pick. The undercut is 2½ to 4½ feet deep and 6 to 12 inches high at the face and 1 or 2 inches at the other end. Anthracite coal is not only too hard to be undercut in this way, but is so brittle and the splinters flying from the coal are so sharp that few miners would be willing to expose face and eyes to the flying fragments. The mining of anthracite also presents difficulties that will not be readily overcome by any coal-mining machine. The coal is too hard to be scraped off by rotating cutter bars, and the percussion cutters are not, in their present form at least, adapted to this work. In addition to the difficulties presented by the hardness of the coal, the steep pitches on which most of the coal must be mined would make it very difficult to adjust a machine and hold it up to its work. These are some of the reasons why coal-cutting machines are not used in the anthracite regions. After visiting the mines and becoming familiar with the conditions, the inventors of these machines have not cared to try them at this work.

The principle of underholding is employed in anthracite mining, but the undercut is from 3 to 7 or 8 feet high and is made by blasting. Sometimes the plan is reversed and the top benches are first attacked and the bottom benches raised afterwards. Gunpowder is preferred to the higher explosives, as these shatter the coal and produce too much fine coal. In fiery (gaseous) workings explosives of the dynamite type are sometimes used on account of the lessened risk, gunpowder making a long flame and being much more likely to fire the gas. The direction of the cleat or cleavage is practically disregarded in anthracite mining, except in so far as it influences the miner in choosing the best location for shots.

While anthracite is too hard to be readily worked with a coal-cutting machine, it is soft enough to be readily drilled with hand-boring machines, and many of these are now in use, in some mines to the exclusion of the common drill. The ordinary drill is dressed to quite a chisel edge and of fish-tail style, is 5 or 6 feet long, and is used as a "jumper" or churn drill. The hand boring machines are simply augers with a positive screw feed and a clamping device, which is commonly fastened in a shallow hole to hold the drill in place. There are many different styles of these drills now in use, but they are all practically the same in principle. An efficient miner, understanding or having the "knack" of using these machines, will bore a hole about twice as fast as it can be drilled. But the miners dislike this kind of labor (the turning of the crank), and many cannot be induced to use them. As the miners commonly are paid by the ton or car or by the number of yards driven, they are allowed to use whichever style of drill they prefer.

Mine railroads.—The gauges of anthracite-mine railways underground range from 2½ to 4 feet; 3 feet and 3½ feet are the gauges in most common use. The rails are iron and weigh from 20 to 36 pounds per yard.

Fish-plate joints are used on main haulage roads; on branches and sidings the rails are commonly spiked down butt to butt. The split-rail switch, or "latch," is largely used, and the ordinary movable-rail switch is also extensively used. "Latches" are made self-closing by bolting them together and attaching them to a metallic spring, counterweights, or an elastic pole held in place by staples at one side of the track. At the foot of slopes and planes the switches are, whenever possible, so arranged that the loaded car runs in to the foot of the plane by gravity, and the empty car is taken off by a switch a few feet above the bottom, so that it runs away from the bottom by gravity. In planning the arrangement of tracks on slopes and planes, it is always considered advisable to place as few switches as possible on the slope itself; to keep the main tracks unbroken; to make them as straight as possible; and to have nothing standing at the bottom in direct line with the slope tracks.

When the topography of the ground permits, the prevailing practice is to build the breaker in direct line with the slope, and to continue the slope tracks up on a trestle to the top of the breaker. The winding engine is either under the breaker (a bad plan) or in a contiguous engine house; but to secure sufficient "lead" between the knuckle pulleys or sheaves and the drum, this must be placed at some distance, and if on higher ground, the arrangement must be such that the cars on one side can pass over or beneath the rope on the opposite side. When the engine and drum are on a lower level, the rope is often passed through a counterweighted slide block playing in guides below the landing floor. The rope passes through a long slot in the floor and through the slide block, but the hole in this is small and catches the rope socket, and the coupling hook and chain are thus held in position for the next car. The counterweight keeps the rope taut, this being necessary to prevent the coils from slipping, springing loose, and overlapping on the drum.

The slope tracks are sometimes continued up above the landing, and the coal is dumped by opening the door, which is then placed on the lower end of the car. The coal falls through an opening into the chute at the top of the breaker. As the weight of the coal is thrown against the door of the car, its weakest point, this plan is not commendable.

In the operation of inside slopes the kind of motive power to be used is the most important problem. As it is especially desirable to reduce the power needed to a minimum, such slopes should be double rigged (with two ropes) whenever possible, so that the resistance to be overcome will only be that due to the weight of the rope and coal and friction, the weight of the mine car being eliminated. But single-rope slopes underground are more common than would be expected, notwithstanding the damages entailed by the presence of steam underground.

Many inside slopes are now operated by engines located on the surface, the ropes being conveyed underground through the main shaft, air shaft, or some old breast that has been holed through to the surface, and more recently through vertical bore holes drilled for that purpose. This latter plan seems to give perfectly satisfactory results.

A few colliery managers are using compressed air to drive the inside slope engines. While this is doubtless a decided advance over the use of steam underground, it can hardly be considered equal to any of the plans where these engines are located on the surface.

The cars are sometimes raised by a small car called a "ram" or "barney," which is attached to the rope. This car runs on narrow-gauge rails laid between the slope tracks. It rises behind the mine car, pushing it up the slope. They are seldom used on main hoisting or inside slopes, but are in great favor for use on dirt planes.

Mine cars.—The cars used in the anthracite mines are of extraordinary size, a size made possible only by the great thickness of the coals now being worked, and made desirable by other conditions not present in other coal fields. As the cars are commonly loaded by gravity, their height is only limited by the height of the gangways and by a due regard to the maintenance of a certain degree of stability. Their width is limited only by the width of the gangways and other passages, and their length by the wheel base and by the sharpness of mine-road curves. Their length rarely exceeds 10 feet, their width 5 feet, and their height 5½ feet, outside measure. Their inside measurements are of course smaller. Their cubic capacity commonly ranges from 70 to 150 cubic feet, or in weight from 1¾ tons to 4 tons. A mine car of average size holds about 100 to 110 cubic feet, or from 2½ to 3 tons of coal. The weight of mine cars is commonly equal to about half the weight of coal they are intended to carry; thus a mine car with a carrying capacity of 3 tons of coal will weigh about 1½ tons.

In shape and in the details of construction the mine cars in use present an almost endless variety. Some are constructed almost entirely of wood, others entirely of iron. In shape they vary from the broad, low car of some of the Wilkes-Barre mines to the high, narrow car used in the Schuylkill region, and from the square, upright pattern to the hopper-shaped style. In thin and flat coal beds the broad, low car is preferred; the hopper-shaped car is best adapted to the narrower gauges when it is desired to increase the capacity without increasing the length or height of the car. Large, square cars of moderate height, with a capacity of 100 cubic feet or more, are slowly but surely replacing all other patterns at mines where the height of the bed, etc., permits; and the present tendency is strongly in favor of "inside wheels," that is, wheels fixed on the axle and running in a box, like the old-style railroad coal cars, instead of the loose wheels running on a fixed axle, such as are in common use at bituminous mines (*a*). Cars made of boiler iron have been tried by several of the operating companies in the past, but it is now almost universally conceded that they are inferior in many

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[a] See Mr. Buck's opinion on loose and fixed wheels in the bituminous mines of the Kanawha valley, page 137.

respects to the wooden-framed bodies in common use. Cast-iron wheels are used almost exclusively. Several different styles of hollow-hub, self-oiling wheels have been tried, but they have not met with general approval from mining engineers. This is partly due to the tendency to condemn every form of loose wheel as inferior to the fixed wheel. The position of mining engineers is doubtless well taken on this point, for with any cars carrying a weight equal to that of anthracite mine cars loose wheels must always be a cause of continual stoppages, accidents of all kinds, irregular running, injury to road-bed, and considerable increase in the net haulage cost.

Underground haulage.—Rope haulage has been tried at only two or three collieries in the anthracite region. The conditions here are not such that much can be saved by this method of haulage at present, but the future will doubtless see many of the deeper mines advantageously operated by some system of mechanical haulage by ropes. Mules and mine locomotives now furnish the motive power for underground haulage.

Under the ordinary conditions of mine haulage, the detentions at turnouts, delays from accidents, imperfections of road bed, and other peculiarities of mine haulage reduce the daily average amount of work performed for each mule to probably not over 50 per cent. of what would be done by the same animal under favorable conditions aboveground. We may therefore assume an effective duty of 25 to 50 ton miles (including weight of mine car) per day, or, say, an average of 40 ton miles. The useful effect in tons of coal is then about 25 tons hauled 1 mile per day by each mule. The average cost of mule haulage underground may be assumed at from 3 to 5 cents per ton of coal per mile. Stabling is commonly provided in a chamber near the foot of the slope or shaft; and the mules, once taken into the mine, are never removed except in case of prolonged suspension of work, accidents, or ill health. These stables are generally kept in as good sanitary condition as stables aboveground.

It is apparent at first sight that mine locomotives can only be employed to advantage on long hauls, or on short hauls where there is enough work to keep eight or ten mules busy. In fiery mines their use must increase the danger of accident, and in poorly ventilated mines they cannot be used on account of the smoke, heat, and the noxious gases given off by the fire. The actual cost of haulage by locomotives, as by mules, varies between such wide limits under varying mine conditions that it is doubtful whether numerical data are of much value. However, for the purpose of comparison certain figures of interest may be quoted. From time to time statements have been published showing an average cost of six-tenths cent to 1 cent per ton per mile; but such estimates invariably contain only the actual daily expenses without proper allowances for depreciation, repairs, etc., and, if not actual misrepresentations, are instances of peculiarly favorable conditions, "good luck," and extraordinarily good management. The actual cost under average conditions cannot be, at present wages, less than 1 cent per ton per mile, and is probably very much nearer 2 cents per ton of coal per mile hauled. I should place it at $1\frac{3}{4}$ to 2 cents per ton per mile.

The mine locomotives in use are similar to those used in bituminous mines, but they are commonly somewhat larger; thus, the following dimensions: Wheel base, 4 feet 3 inches; gauge, 3 feet; drivers, 2 feet 2 inches; tubular boiler, 56 tubes; grate area, about 5 feet; cylinders, 8 inches in diameter, with 12-inch stroke; dome, 1 foot 6 inches; tank over boiler, capacity 220 gallons; weight, about 7 tons. Many engines of larger size are used, thus: Cylinders, 9 inches in diameter, with 14-inch stroke; weight complete, 8 to 9 tons.

Hoisting machinery.—The winding engines now in use are nearly all built with horizontal cylinders and ordinary plain slide valves. A very large number of geared engines are in use, in which the driving pinion is connected by "second" or "third motion" to the drum, and such engines are known as "second" or "third-motion" engines, in contradistinction to the direct-acting or "first-motion" engines, in which the main driving cranks are placed on the drum shaft. As the various friction gears are used to but a limited extent in the anthracite mining region, and almost never on main hoisting machinery (their use being confined to short planes, breaker planes, dirt planes, etc.), engines with expansive valve gear are not used. The journals, drum shaft, pedestals, connecting rod, and piston rod are all made larger than on ordinary engines; this is especially necessary in the large first-motion or direct-acting engines which are now rapidly replacing the old-style geared engines.

Winding-engine foundations are, almost without exception, built of stone. Any sandstone that may be found in the neighborhood at all suitable to the purpose is used. The stones are rarely dressed with care, except, perhaps, the upper courses, finish not being considered much of an object. The height of the pillars is made sufficient to give clearance for the drum and for any connections beneath the engine floor—in other words, all the cellar room needed—and to give sufficient weight to insure absolute stability and rigidity. The holding-down bolts are built in the masonry, instead of being placed in bolt holes left for that purpose. In placing the large engine at the Pottsville deep shaft the bolts were inserted in bolt holes drilled with a diamond drill after the engine pillars were finished. The use of timber seats is now limited to small engines, engines erected for temporary use, and small engines in which the bed plate is all cast in one piece. For winding engines timber seats are not now considered allowable. Even in underground work the adoption of masonry pillars and seats for winding engines and pumps is becoming common, and many engineers consider it the only good practice.

The large direct-acting winding engines now coming into such general use are of course built in pairs. Their cylinders range from 16 or 18 to 45 inches in diameter, and their stroke from 3 to 5 or 6 feet.

Drums.—Conical drums are coming into general favor for use at shaft collieries, but as yet only a few have been built, and cylindrical drums are still in general use at both slope and shaft coal mines. Cylindrical drums of moderate size are constructed of heavy cast-iron spiders, with six or eight arms, covered with a lagging of timber 5 to 8 inches thick. Some very large drums are in use; thus, at Kohinoor drums 20 feet in diameter are used; but at most collieries the drums are between 8 and 16 feet in diameter. Very few shaft collieries are now operated with drums less than 10 feet, and the majority of shaft workings have drums 12 feet and upwards in diameter. Drums at slope collieries commonly range from 8 to 12 feet in diameter. It is now a well-recognized principle that the drum should always be more than 1 foot in diameter for each one-fourth inch in the diameter of the rope; thus, for a rope 1½ inches in diameter the drum should exceed 6 feet; and in the anthracite regions these figures are commonly doubled.

Wrought-iron band brakes are used to the almost entire exclusion of other forms. They are sometimes operated by a treadle, but more commonly by a hand lever. On some large winding plants steam brakes have been tried, but they are apparently open to several objections, chief among which are their rapidity and violence of action. This has been overcome in one case by controlling the throttle with a slow-motion screw, so that the steam is admitted very slowly; but it is evident that this cannot be an entirely satisfactory method. Some very large "first-motion" engines are supplied with a steam reverse, to assist the engineer in throwing over the reversing lever.

Cage rests, keeps.—These do not differ materially from those in use at English collieries. The "stops" to prevent the mine cars from running into the shaft and from running off the cage are also similar to those used in other mining districts.

Cages.—Single-deck cages are used. When the deeper parts of the coal basins are worked, years hence, it will doubtless be found necessary to introduce double-deck cages, but at present they are not needed. Iron cages are largely used, but a cage constructed of wood, with iron tie rods and braces, doubtless gives better service and is much more readily repaired when injured in any way. Self-dumping cages are now only used in breakers for raising the cars from the ground to the "platform chute." "Gunboats" (a name given to large self-dumping "skips" constructed of plate iron) are used at many slopes on which the dip is too steep to raise the mine cars without the use of a slope carriage or cage. The gunboat is made to hold one or two carloads of coal. Gunboats are now also used to some extent for raising refuse (culm, rock, slate, etc.) on dirt planes.

Safety clutches.—The law requires "an improved safety catch" on every carriage used for lowering or hoisting men; therefore safety clutches are used throughout the anthracite region. They all depend upon some kind of a spring to set them in operation; rubber cushions, spiral and straight and torsion springs are used in the different forms of clutches in use. The clutches which have given the best results are those in which the dogs are cam-shaped, with serrated surfaces that grasp the guide. Chisel-pointed bars thrown against the guide are uncertain in action; clamps holding by friction only have not given satisfactory results; and cam-shaped dogs with a chisel edge have been found unreliable, and often do considerable damage to the guides.

Other safety attachments to the winding machinery are the bridle chains, bonnets or cage covers, and detaching hooks. These latter are not viewed with favor here, although largely used in European mines. A winding engine under perfect control, an efficient brake, and a sober engineer, are better safeguards against overwinding than all the detaching hooks that can be invented. Such appliances are at best uncertain in action, and are at times the cause of serious casualties. Indicators driven by positive gearing from the winding machinery are now coming into general favor. They are certainly a great improvement over the old-style chain or string indicator, and, with the addition of gongs to warn the engineer against overwinding, are all that could be desired. The mouths of all shafts are inclosed by gates, and those not in use are securely fenced in or covered over. The gates are automatically opened by the car running off the cage, or are lifted by the cage.

Signaling is done by means of an ordinary wire and hammer and plate or gong; but in addition to this every colliery is provided with speaking tubes, so that orders may be freely transmitted from top to bottom, and *vice versâ.* These speaking tubes are commonly made of ordinary 2-inch iron pipe. Instead of blowing a whistle to attract attention at the other end, the common practice is to rap on the pipe.

Speed of hoisting.—Where a large output is handled, the necessity for all the safeguards that can be thrown about the mine and the individual employés becomes at once apparent. Thus a colliery putting out 1,000 tons of coal a day requires rapid and uninterrupted work. As a mine car of coal will make about 2 tons of merchantable coal, 500 cars of coal must be raised. To do this in eight hours the cages must average 62½ runs per hour, or, say, a maximum speed of 70 runs per hour; or one winding, including shifting, signaling, etc., in about fifty-one seconds. The actual time of winding and seating the cage on the wings would be about thirty-five seconds. If the depth is 600 feet, the speed in the middle of the run must be about 40 feet per second. At the Pottsville shaft, the depth being 1,600 feet, an average speed of 35 feet per second is easily made, which means a speed of 40 to 45 feet per second in the middle of the run. It does not seem probable that any practical work will be accomplished much more rapidly than this, and it is extremely doubtful whether it is desirable to contemplate any attempts to increase the running speed beyond, say, 45 to 50 feet per second. However, with the large conical drums, with traveling guide to keep the rope in the scroll (groove), with large (16 to 20-foot) tension-bar sheaves and phœnix column head frame, with detaching hook, safety governor, steam brake, and steam reverse, a plant like this Pottsville shaft winding plant may safely attain results that could not be complacently viewed as a legitimate performance by inferior machinery.

Ventilation.—In the deeper parts of the Wyoming basin now being developed the best means of securing adequate ventilation is the most important mining problem. In the deeper parts of the Schuylkill and Second basins this problem will also be of engrossing interest, as fire-damp is there also extremely troublesome. In the Wilkes-Barre district workings on the lower levels are now opened with two airways driven parallel to the gangway, each being 6 or 8 feet high by 12 feet wide, and even when this is done it is sometimes necessary to let the gangway stand several months to drain the gas from the coal before it is at all safe to attempt opening out the breasts. When two airways are driven, the gangway is located between them. The air is conveyed into the face (heading) along the gangway, and is here split into two currents, one being sent out through each airway. That on the lower side of the gangway (next to the solid) is frequently explosive, although 40,000 to 60,000 feet of air per minute may be passing through it. Throughout this Wilkes-Barre district the airways are commonly from 70 to 100 feet in cross-sectional area. In the small Lehigh basins and in workings on the margins of the larger basins from 25 to 40 square feet is considered large enough, except for the main return airways from extensive workings. Cross-headings between breasts, and those connecting the airway and gangway, are always driven as small as they can be safely made. This is, of course, owing to the fact that they are for temporary use only, and must afterwards be closed by stoppings, brattice, or doors.

Doors located on main traveling ways are substantially constructed, with a heavy sill built into masonry on each side, and the door itself is hung at a slight angle, so that it is self-closing. All of the main doors on gangways are opened and closed by a doortender ("trapper boy"), whose sole duty is to open and close the door for the passage of cars and men, and to see that the door is kept constantly closed at all other times. On such gangways the doors are in pairs, at a sufficient distance apart to allow one door to be closed after a trip of cars has passed before the other door is opened.

Stoppings to close old workings, cross-headings, etc., are commonly built of masonry, but in non-gaseous mines they are often of boards. In airways they are made from 1 to 3 feet thick; to close old workings in thick seams these walls are sometimes 4 to 8 feet thick at the base. Thick stoppings must always tend to limit the effects of a mine explosion, and are of inestimable value in re-establishing ventilation after an explosion.

Brattices are necessarily used largely in nearly all anthracite mines; but as it is practically impossible to make them even approximately air-tight, there is a growing feeling against their use, and especially against long brattices.

Overcasts, or airway crossings, are avoided whenever and wherever it is possible to omit them; but when they must be used, they are now built as substantially as possible, so that the risk of destruction by any mine disaster is reduced to a minimum. To remove the possibility of such an occurrence, airway crossings are sometimes made by driving a cross-cut airway in the roof rock over the gangway, separated by several feet from the main haulage way.

Very few anthracite mines are now ventilated by furnaces. For mines of shallow depth fans are undoubtedly more economical, and for deep mines, generating gas, the use of furnaces underground is accompanied by too much danger.

Safety lamps.—The use of safety lamps is now generally restricted to work necessary in opening new workings, driving gangways, airways, etc. Safety lamps by no means insure safety; and as this fact is coming to be more generally appreciated their use in mining is being restricted, and naked lights are used almost entirely, safety being insured in all the working places by a sufficient current of air to carry off and so dilute the gas as to render it harmless.

Fans.—Fans of the Guibal type are now regarded by nearly all anthracite mining engineers as superior to any other style, and these fans are surely replacing all other forms. A few double fans are in use, but the claims made for ventilators of this class cannot be substantiated. The actual work of a fan is dependent upon the speed of the tips of the vanes and is practically independent of the width. A double fan is about equal to a single fan of width equal to the two joined together, and it will practically do only a trifle more work than a single fan of ordinary width. Fans are commonly made with a width equal to about one-third their diameter, and with inlet orifices having a radius equal to about one-half the radius of the fan. The spiral commonly commences about opposite the throat or discharge, and the discharge or outlet when the shutter is wide open is about one-half the radius or less; but this orifice should of course be made to meet the requirements of the mine and the calculated or supposed performance of the fan. A peripheral velocity of about 3,000 feet per minute is commonly considered to be about as high a speed as it is well to adopt under ordinary conditions, but in emergencies the fans are sometimes run up to double this speed. Very large fans are run relatively slower than small ones. As yet comparatively few fans more than 20 feet in diameter are in use, although a few 30 and 35-foot fans are found in the Wyoming district. A very large number of 16 and 20-foot fans are in use, and very many 12 and 14-foot fans, but very few fans less than 10 feet in diameter are to be seen in any part of the anthracite region.

Economy in mining.—It may be well to refer here briefly to some of the principles governing every mining engineer in his endeavor to reduce the cost of mining and preparing coal. Economy must be exercised in every branch and department of the business. This is axiomatic; but in no business is a false economy so surely followed by ultimate increase in cost as in anthracite coal mining. Timber of good quality, well-built cars, cages, and framing of all kinds, substantial machinery constructed of the best materials, thoroughly good fans and pumps and boilers, these are all necessary if coal is to be cheaply mined and prepared. In the arrangement of all machinery, and in devising the mining methods, one principle must always be kept in view as of pre-eminent importance, namely, the reduction to a minimum of the labor of handling the coal by moving it entirely by gravity if this is at all possible. The coal runs to the mine car and is loaded by gravity, it is then raised to the surface and to the top of the breaker, is dumped and flows down over the screen bars, through the crushers, through the screens, down the picking chutes, through the jigs into the pockets, and thence into the railroad car, all by gravity. The same principle applies to unwatering the mine, to the removal of refuse, and to the conveyance of timber and supplies into the mine. Switches are made automatic, so are also car locks; the cars are dumped by a self-acting dump or some other automatic device; and, in short, hand labor everywhere is reduced to a minimum by the employment of automatic devices, by replacing it by machine work, or by some arrangement by which it is rendered unnecessary.

Surveys.—Only commendatory criticism can be made of the anthracite mine surveys. They are second only in accuracy to some tunnel work, and can be given to the engineers of all countries as examples of quick, accurate work from methods not only satisfactory in results but expeditious and trustworthy, although employed in the presence of numerous difficulties. The geological maps constructed by the Pennsylvania Geological Survey from these mine surveys are sufficient testimony to this fact.

Explosions.—Disasters from the explosion of firedamp are still common in the anthracite regions, but since the passage of the mines ventilation act there have been few great catastrophes. In the ten years from 1870 to 1879 inclusive there were only 235 deaths from this cause, an average of 23½ per year. During these years 679 explosions occurred, thus showing there was, on an average, but 1 death to every 3 explosions. In addition to those killed, 902 persons were injured by these explosions. These figures very clearly corroborate the assertion that nearly all the explosions of the past ten or fifteen years have resulted from the accumulation of small bodies of gas in cavities or near the roof in the working places, and that these accumulations would rarely occur, and accidents from such accumulations would be rarer still, if the miner exercised the proper precautions. Familiarity with danger breeds recklessness, and probably nine-tenths of such accidents are directly traceable to this carelessness on the part of the miners and laborers. The ventilating methods in general use, and the system of periodic inspection of all parts of the mines by fire bosses, insure comparative immunity from serious casualties involving the whole of a mine or even a panel of workings; but the occurrence of small explosions from local accumulations cannot be prevented when the miner fails to obey instructions and is heedless of the warnings or directions given by the fire boss or superintendent. The dust of anthracite mines is apparently not a direct cause of explosions, nor does it appear that this dust is auxiliary in producing explosions or participates in the combustion during an explosion. In this it evidently differs widely from the behavior of the dust of some bituminous mines.

Miscellaneous accidents —The principal source of accidents in anthracite mining is to be found in roof falls and falls of coal. Thus, from 1871 to 1880, out of a total of 7,886 casualties, 2,827, or 36 per cent., were caused by rock, slate, or coal falling on the miner from the roof.

Accidents in Pennsylvania anthracite mines, 1871 *to* 1880, *inclusive.*

Cause.	Fatal.	Not fatal.	Total.	Per cent.
Roof falls	979	1, 848	2, 827	36
Explosions	239	982	1, 221	16
Miscellaneous	989	2, 849	3, 838	48
Total	2, 207	5, 679	7, 886	100

Many of these casualties are unavoidable, but a large percentage of the accidents from falls of roof and coal could be avoided by closer attention to the placing of props, by more careful inspection of the roof, and by the exercise of great caution whenever blasting is being done in adjoining workings. Accidents of this class commonly occur at or near the working face where the miner is at work. Although they form 36 per cent. of the total casualties, they constitute over 44 per cent. of the fatal accidents, thus showing them to be more serious than accidents of any other class.

The accidents embraced under the head of "miscellaneous" are divisible into a multitude of different classes, no one of which is of especial interest. Premature firing of blasts, kicks from mules, accidents from mine cars and locomotives, from machinery, by falling down shafts and slopes, by drowning, by suffocation, are some of the many causes of the 3,838 accidents embraced under this head.

The accidental deaths from all causes may be considered in late years to average 220 per year, and the number injured to average about 570 per year; but this does not include many trifling injuries not reported to the mine inspectors.

Mine fires.—The means most successfully used in fighting mine fires are:

1. Throwing water directly on the burning material. This can only be done when the fire is not extensive and is accessible.

2. Drawing the burning material out of a breast; this being possible only in the case of steep-pitching breasts.
3. Sealing the mine to exclude the air.
4. Sealing the mine and introducing steam.
5. Flooding with water.

The last is the only sure method, but as it always involves enormous expense, other methods are generally tried before resorting to this. The carbonic acid gas plan is no more likely to succeed than sealing the mine. If the mine can be rendered nearly air tight this method will succeed, but if the mine is sealed in this way the fire will make sufficient carbonic acid gas to smother itself. For this reason the plan does not receive favorable consideration from mining engineers.

Preparing coal for market.—For domestic use anthracite coal must be separated into grades of approximately uniform size, this being necessary to insure an even distribution of the draught. The largest size, "lump," which consists of pieces from the size of a large cocoanut up to lumps weighing 50 to 100 pounds, is used principally in smelting iron ore and for other metallurgical purposes; "steamboat" is commonly from the size of a small cocoanut to that of a human head, and is used for metallurgical purposes and for making steam; "broken" is also largely used for steam making; and the smaller sizes, "egg," "large stove," "stove," "chestnut," and "pea," for domestic use; but the smallest sizes, "pea" and "buckwheat," being much cheaper than the intermediate grades, are now rapidly replacing the larger sizes for use under boilers.

The coal is broken, sized, and cleaned in a large structure known as the "breaker." The mine cars are raised to the top of this building, and the coal is dumped into a shute, down which it slides over a series of grate bars placed about 4 inches apart. The smaller sizes fall through these bars and pass into a "dirt screen" or "mud screen." This screen, like all others used, is a revolving cylindrical screen, with either woven wire or cast-iron grating for the screen mesh. The fine dirt passes through this mesh and the coal then goes to the "broken screen," which has a large mesh, allowing all to pass through except the "broken coal." The coal passing through this screen goes to the "main screen," along with the other coal coming from the rolls. The large coal that passes over the grate bars slides out upon a platform, where the best pieces are picked out and thrown into the lump-coal chute. When "steamboat" coal is to be made, it can be separated by placing large grate bars in this chute. The slate and rock are thrown into the "rock chute," and the poorer coal, fragments containing slate, "rough coal," etc., are thrown into an opening in the platform, beneath which are the "crusher rolls." These rolls are heavy cast-iron cylinders with pyramidal steel teeth; they are commonly about 30 inches in diameter and 3 feet long. The coal crushed by these rolls passes to a "broken screen," which also sometimes separates out the "egg coal," and thence to the "main screen." The main screen separates the stove and chestnut, and sometimes the egg also; and the smaller sizes go to the "pea screen," which separates the pea and buckwheat from the "dirt." But it must not be supposed that the arrangement of all breakers is planned after this method. The screens are variously arranged to meet the peculiar requirements of the coal. When the coal comes wet from the mine the dirt must be washed from it, this being accomplished by perforated pipes or troughs, from which a shower of water constantly falls on the screens and also upon the coal in the main shute on the grate bars.

The following figures give the maximum range in the sizes of mesh used for separating the coal into the different sizes:

Lump coal passes over bars placed $4\frac{1}{2}$ to 9 inches apart.
Steamboat coal passes over bars $3\frac{1}{2}$ to 5 inches apart, and through bars placed about 7 inches apart.
Broken coal passes over a mesh $2\frac{3}{8}$ to $2\frac{7}{8}$ inches, and through a mesh (or bars) $3\frac{1}{4}$ to $4\frac{1}{2}$ inches.
Egg coal passes over a mesh $1\frac{3}{4}$ to $2\frac{1}{4}$ inches, and through a mesh $2\frac{3}{8}$ to $2\frac{7}{8}$ inches.
Large stove coal passes over a mesh $1\frac{1}{4}$ to $1\frac{7}{8}$ inches, and through a mesh $1\frac{3}{4}$ to $2\frac{1}{4}$ inches
Small stove coal passes over a mesh 1 to $1\frac{1}{4}$ inches, and through a mesh $1\frac{1}{4}$ to $1\frac{1}{2}$ inches.
Chestnut coal passes over a mesh $\frac{5}{8}$ to $\frac{3}{4}$ inch, and through a mesh 1 to $1\frac{1}{4}$ inches.
Pea coal passes over a mesh $\frac{3}{8}$ to $\frac{5}{8}$ inch, and through a mesh $\frac{5}{8}$ to $\frac{7}{8}$ inch.
Buckwheat coal passes over a mesh $\frac{3}{16}$ to $\frac{3}{8}$ inch, and through a mesh $\frac{3}{8}$ to $\frac{5}{8}$ inch.
Dirt passes through a mesh $\frac{3}{16}$ to $\frac{3}{8}$ inch.

The coal falls from the screens into chutes lined with sheet iron, known as "telegraphs" or "picking shutes," down which it passes to the pockets or hoppers, from which it is loaded into the railroad cars for market. Boys sit along these chutes (or astride them), and pick out the fragments of slate and bony coal. The slate can be removed in this way from all of the larger sizes, but to clean the chestnut and pea coal by hand picking would be very expensive; hence, these sizes are commonly either not cleaned at all or the slate and sulphur are removed by jigs. Some screens are provided with a "slate-picking segment," in which the mesh consists of long, narrow slits, through which the slate, being flat, can readily pass, accompanied only by very small pieces of coal, which can be saved by passing the slate and coal over an ordinary round or square mesh large enough to pass the coal but too small to admit the slate.

Waste in mining and preparing anthracite.—The waste in mining includes not only coal left in pillars to support the overlying rocks, coal lost by a "crush" or "squeeze," but also all the fine, unmerchantable coal "dirt" made by blasting and handling, and coal left in the mine mixed through the "gob." The waste in preparing includes the fine coal culm or dirt made by the rolls in breaking the coal, fine coal made by the screens, jigs, and shutes, and by loading, and also the coal lost by adhering to lumps of slate, etc., sent to the waste piles. I estimate the average waste throughout the anthracite region from these causes as follows:

Percentage of total coal contained in the ground.

	Per cent.
1. Coal left in pillars and lost by being crushed, etc	45
2. Coal lost (in mine and at breaker) by adhering to or becoming mixed with refuse	7
3. Fine coal made by blasting and handling	8
Coal wasted, exclusive of breaker waste	60
Coal reaching the breaker (excluding fine coal, etc.)	40

Assuming the waste made by breaking at 10 per cent., from screening at 4 per cent., and waste at "lip" screens, etc., at 2 per cent., making 16 per cent. of the amount reaching the breaker, we have:

	Per cent.
Coal reaching breaker	40.00
4. Breaker waste (16 per cent. of 40)	6.40
Coal loaded into cars and sent to market	33.60
Coal wasted	66.40
Total	100.00

To reduce this enormous percentage of waste is of such paramount importance that it is somewhat surprising that concerted measures are not taken by the different mining companies looking to the development of improvements in both the mining and preparing of coal. If this waste is to be largely reduced it is evident that improved mining methods must be adopted; that the 45 per cent. left in pillars, etc., must be reduced.

The following improvements have been suggested; some of these plans are now being experimented with, and the reported results are favorable to their more general adoption:

1. The "boundary" plan of leaving thick pillars to divide the workings into panels, to localize the effects of a squeeze developed by robbing out the pillars.

2. The plan by which narrow workings are first driven, leaving every pillar of extra thickness until the mine is exhausted, and then robbing the pillars out. At many collieries the adoption of this plan would certainly increase the percentage of coal mined from 10 to 20 per cent. A modification of this plan is made by leaving a 60-yard pillar between each two breasts, and opening two breasts in each pillar after the gangway has been driven to the limit, work then being commenced in the pillars farthest from the outlet.

3. The plan of driving to the limit before opening any workings. This would undoubtedly result in a large increase in the percentage of coal obtained.

4. Veith's "boundary" plan, in which the pillar and breast stumps above the gangway are left of more than ordinary thickness, so that the pillars can be robbed out as soon as a breast is worked out, without fear of closing the gangway.

5. Brown's panel system, which is adapted to thick beds dipping from 15° to 35°.

6. The "rock-chute" plan of opening the gangways in a bed underlying the seam to be worked, and tapping the main seam by rock chutes. Where this plan can be adopted a large increase in percentage of coal mined can undoubtedly be made.

7. Long-wall and panel workings in flat beds of moderate thickness may be successful, but the possibility of using either system in the anthracite region is very doubtful.

The utilization of fine coal "culm" or "dirt" by manufacture into artificial fuel has not been financially successful, and it seems probable that we must look to some method of burning this material in its present form rather than to its manufacture into an artificial fuel. An average of between 12 and 15 per cent. of the total contents of the coal beds now worked is wasted by being converted into culm or dirt.

COAL MINING IN THE KANAWHA VALLEY OF WEST VIRGINIA.

By Stuart M. Buck.

Kanawha coal has come into some prominence within the last few years, and the object of these notes is simply to record the conditions under which the business is now carried on, without professing to bring forward anything new.

General description of the district.—The Kanawha coal field is a general term, including all the coal seams opened on the Kanawha and New rivers with their tributaries, and may be regarded as covering the newly developed Flat Top district; but it is generally limited to that part of the field having for an outlet the navigable waters of the Kanawha, or the line of the Chesapeake and Ohio railway, which descends the valley of the Greenbrier to the New river, and follows that stream till it joins the Gauley at Kanawha falls, where the united streams take the name of Kanawha.

The New River valley is a narrow cleft in the mountains, and is frequently compared with the western cañons; but the Kanawha valley gradually widens, and affords bottoms suitable for farming. The New river is a succession of pools and rapids, but the Kanawha in ordinary stages of water is navigable for light-draught steamers to Cannelton, within 10 miles of the falls. The railroad follows the valley to Scary, where it leaves the Kanawha and takes a more direct course to the Ohio, which it strikes at Huntington, near the mouth of the Guyandotte river.

The general geological structure of the country is very regular, and the topography of the region allows the employment of very simple methods of handling and shipping the coal, but there is a great variety in the character of the coal mined from the different seams, and in the method of treatment. Up to the present time mining operations have been limited to the lands immediately adjoining the river and to a few tracts within 5 or 10 miles, reached by short lines of railroad specially constructed for their development. Coal was also shipped for many years from the Peytona cannel mines, on Coal river, depending on a system of locks and dams for slack-water navigation to the Kanawha. The Peytona mines are now abandoned, and the locks and dams are out of repair. The natural features of the country are such that the way is open for additional lines of railroad through many side valleys, opening up a greatly increased area.

The mountains rise 500 to 1,200 feet above the river level, and contain so much coal in sight, cropping out in nearly horizontal strata, that there has been no inducement to make any thorough search by boring for coal below the river level. The bore holes made have been mostly for salt wells, and the reports of coal struck in them are not to be relied on. The general and regular dip of the coal indicates what may be hoped for on boring in parts of the country where any of the coal seams have passed below the river level, but experience in working the seams above water level shows that they all have their local basins of maximum thickness, and that coal, which is valuable and apparently regular in one place, becomes so pinched or changed in character within a few miles as to be quite worthless, so that geology alone will hardly warrant any large expenditure for the working of the lower seams after they have passed out of sight.

The general dip of the Kanawha coal field is to the northwest, and on approaching from the east along the line of the Chesapeake and Ohio railway the first coal met is at Quinnimont, where it appears high up on the mountain. This is geologically one of the lower coals of the New river series, which are worked at frequent intervals from Quinnimont to Hawk's Nest bridge for 30 miles, and then disappear below the river; while the next higher or middle coals of the Kanawha series come into prominence for the next 40 miles, disappearing in turn near Charleston, to be succeeded by the third series, which is worked at Raymond City.

The Kanawha has been called the special field for small capitalists. This is still true in many places, but as competition increases and the margin of profit becomes less it is necessary to extend operations and to work with a larger capital. There is nothing of special novelty in the machinery and appliances or in the plan of underground working here, but as there are slight differences in different districts, and the methods are gradually changing, it may be of interest to put on record the present system.

At present the whole coal field is suffering from the overestimates which have been made by its explorers in times past. Geologists and mining engineers who have been familiar with the more irregular structure of other regions seem to have been deceived here, and to have relied too much on the regularity of the formation. In some cases they have no doubt duplicated the seams, and in others they have been content with finding the outcrops of known seams, and then have taken the measurements of coal and reports of quality from points where these seams have their fullest development, trusting to the known regularity of the formation to confirm their report, and ignoring the fact that each seam has its area of special value, either in the matter of thickness, or quality, or both.

Thickness of the beds.—It is usual to hear of 50 feet as the thickness of workable coal in seams of 3 feet or over, but unfortunately most of these sections are grossly exaggerated, and many of the seams which appear so well on paper prove on trial to contain impurities which render them worthless at the present time. Doubtless such sections may be proved in places, but among the mines now working a total section of 12 feet would be regarded as very favorable. The limit of workable thickness on the Kanawha is usually stated at 3 feet, but several seams are worked which average less, and probably 30 inches may be regarded as the minimum where there are special inducements afforded by the ease of mining or by the superior quality of the coal.

Ownership.—West Virginia coal lands are generally held in large grants, and often under conflicting titles. Many of the tracts to which a clear title could be found are so involved by mortgages that they can only be taken as a whole by large capitalists, and cannot be divided to suit the requirements of individual operators. The river bottoms and lower slopes are often held under different titles by small farmers who control the approach to the coal lands in their rear.

Character of the coal.—The New River coal is quite soft, with very indistinct faces; contains much mineral charcoal; has a low percentage of volatile matter, and is used principally for steam purposes and coke making. It is easily mined, and requires but little powder. It ranges from 30 inches to 5 feet in thickness, and requires less skill on the part of the miner, as it is taken, coarse and fine, just as it comes from the pick. The Kanawha coals are classed as splint, gas, and cannel.

Splint is used mostly for domestic fuel and high-grade steam coal. It is noted for its toughness and regularity of cleavage, allowing it to be prepared in an attractive shape for market. It withstands the handling and exposure of a stockyard much better than ordinary bituminous coal. It is rich in volatile matter and gives very good results as a gas coal, but not better than other softer and cheaper coals. Splint coal requires more skill and care in mining than the softer coals, as the miner is paid on the basis of the lump coal which passes over the screens.

Gas coal is softer coal, and can be mined more cheaply than the splint, while it gives as good results in the retorts. It is used almost entirely for gas making, and to a very limited extent for steam purposes.

Splint coal and the softer grades often form distinct bunches in the same seam, and, if possible, they are then mined and shipped separately.

Cannel coal is now being mined only at Cannelton and on Paint creek, and is used principally by the gas works as an enricher for other coals. It is of very irregular occurrence and limited in area.

Number of seams.—There is still some uncertainty as to the identity of the coal seams in different parts of the district, which will no doubt be cleared up by the publication of Professor White's examinations made during the summer of 1884, some results of which have been given on pages 91 to 97 of this volume. There are at least eleven distinct seams which are now being worked at one or more points, but there are very few properties that will show more than two of the number in workable condition, although the section at some points includes seven seams.

Royalty.—About half of the coal now being mined is from leased land, and the royalty is variously paid, either as a fixed annual charge without reference to the quantity mined, or as a payment directly proportioned to the output; or, lastly, as a minimum, giving the privilege of mining a fixed quantity, any coal mined in excess being accounted for in addition. The royalty is sometimes regulated by a sliding scale, to encourage a large production.

The royalty may be on the run of the mine, as the coal comes from the pick. This is common with the coking coal of New river. It may be on all coal passing over a screen of 1¼ to 1½-inch opening, disregarding the nut and slack. This is usual at the splint mines. It may be on coal passing over a five-eighths inch screen, disregarding only the slack. In general the rate of royalty approaches 10 cents per long ton.

System of mining.—The system of mining adopted on the Kanawha is almost exclusively that of room and pillar work. Long wall has been tried in a few instances, but most of the attempts have been failures, and the mines where it is now in progress have advanced so short a distance that no decided deduction can be made from them. Long-wall retreating has never been tried here on any large scale, and where long-wall advancing was attempted in the past the effort was made to keep the roof up by timbering. Naturally it resulted in failure. The local prejudice against this method is strong, but there are some coal seams here where it could undoubtedly be made a success. The difficulties in the way are drainage and irregular work. Very few of the coal seams can depend on natural drainage over any extensive area, owing to the slight dip and the number of local basins or swamps, so that as soon as the roof settles the mine is in danger of being flooded, and the water collects in so many scattered depressions that it cannot be removed economically.

The principle of long-wall work requires uninterrupted progress, so that the roof may settle regularly, and soon enough after the removal of the coal to prevent excessive pressure at the working face, allowing the miners to continue their work step by step under a new roof. Irregularity of work may prove a serious objection to this method of working. River shipments are liable to be interrupted by low water or ice, and the railroad car supply is sometimes cut off for a week at a time. There is danger that during such a stoppage the whole working face might be lost.

The dip of the coal on the Kanawha, though often irregular, is comparatively light, so that after the course of the main entry has once been determined, it is not usual to make any change, but to lay out the work at right angles.

At some of the New River mines the dip is heavy as well as irregular, so that the work cannot be laid out in advance, and the plan is necessarily changed from time to time to conform to the grade.

The location of the entries or gangways depends in general on the grade for hauling, the drainage of the mine, the ventilation, and on a convenient division of the land; but in most of the splint and gas coal mines an important consideration is to so lay off the work that the rooms, which are usually turned at right angles to the entries, may be driven squarely against the natural faces of the coal. In the harder splint coals it is almost impossible to induce miners to work rooms in any other direction, and such work is always injurious to the coal, shattering it more in blasting, and so lessening its market value.

The entries are usually driven 9 feet wide, and all gob is then removed. Sometimes they are 12 or 15 feet wide, with gob on one rib, and as an extreme case 30 feet wide. In this instance the coal is thin, and the roof slate, which is shot down for headroom, is all stowed at the side of the roadway.

Both the face entry and the butt entries are usually driven with parallel air courses, separated by a pillar of 20 to 40 feet, which is cut through for ventilation at intervals of 75 to 150 feet; but when the opening of the mine is not being rapidly pushed, the face entry is often ventilated by a parallel room driven ahead of the others. After opening out the mine by means of the first pair of butt entries, it is a common practice to drive the remaining butt entries single, allowing every third room to hole through for ventilation.

The rooms are opened from the entries with a width of 9 to 15 feet, and driven narrow for 18 to 30 feet, when they are widened to 20, 30, or even 45 feet. The usual width is 24 or 27 feet. The widest rooms are worked with two tracks, and have some of the advantages of long-wall work. The varying width depends on the character of the roof, the hardness of the coal, and the amount of gob for which stowage must be found. It is sometimes considered easier to keep the roof up in a wide room than in a narrow entry. The rooms are usually driven 300 feet long, but vary between 200 and 500 feet. When the pillars are to be drawn, the rooms are usually widened on one side only, and the room road is then laid along the rib, ready for use in drawing back the pillar; but in clean coal, free from gob, and especially in thin seams, it is often easier to relay the track after taking out the coal on a center road.

The pillars left between the rooms are usually 12 to 15 feet thick, but vary between 8 and 30 feet. The thinnest pillars are not drawn at all, or are merely thinned and broken through in places. The pillars of medium thickness are drawn back by a single room road, and those of 24 feet or over are either worked from the double room roads on each side, or else are split and worked by a special road. Room pillars are drawn back to within 40 or 60 feet of the entry, and the stumps are left to support the entry roof. The entry pillars and the room stumps are left till the entry is worked out, when they also are drawn.

Pillars are usually drawn as soon as the rooms in a limited section are finished, but some mine operators believe that the probably increased flow of water, when the roof is let down, more than counterbalances the value of the pillar coal. In such case the thin-room pillars are abandoned and the entry pillars are left till the mine is exhausted. In the hard splint mines, which make a specialty of lump coal for supplying stock yards, the pillar coal, after sustaining the pressure of the roof for a time, becomes brittle and will not bear handling. It then ceases to be merchantable coal.

So many of the Kanawha mines are high on the mountain that unusual facilities are offered for rear and side openings. In consequence of this the general plan is often more irregular, as the temptation is strong to avoid the expense of airways by pushing single entries through to the crop, on the plea that when that is once reached there will be sufficient ventilation.

Cutting the coal.—The undercut, as in other bituminous mines, is usually 3 or 4 feet deep, and is made in the coal immediately above the floor. In some cases a soft slate below the coal forms part of the cut, and rarely the work is done in a middle parting. Powder is used freely at most of the mines, but the block coal on Davis creek and the soft New river coals require very little. Wedges are only used incidentally for breaking down coal already shattered by powder. Black powder is used exclusively in blasting the coal, and high explosives are seldom used even in rock work. No attempt has been made to experiment with lime cartridges or other substitutes for powder.

Tools.—Most miners still use the ordinary coal drill, or jumper, but many of them, especially in the softer coals, employ the breast auger. A ratchet drill is much used on New river for drilling slate holes, and in the harder coals a limited use is made of the patent drills manufactured by Burk, Grimm, Howell, and others. The success of all these depends on careful handling, and they will be slow in displacing the jumper. Power drills, driven by compressed air, have never been introduced.

Machine mining has been tried to a limited extent, but not under favorable circumstances. Both the Lechner and the Harrison machines have been used; the latter at two different mines. Much difficulty was found in keeping up the repairs of the Lechner machines, and when work was suspended and the mine changed hands they were abandoned. The Harrison machines are very effective and require very little repair. Of the two plants introduced here one was removed to Ohio, where it is reported to be doing good work; the other is still at work, and consists of three Harrison machines and an Ingersoll compressor. These machines are being used where it was found very difficult to get any hand labor on account of the hardness of the mining. They are now undercutting in a lower bench, consisting of tough, spongy coal, lying below the usual mining streak. This gives an excessive amount of waste material to handle and makes impossible any true comparison of efficiency. The test of the machines is very severe, as the coal does not fly freely from the pick, which often hangs and remains fixed in the cut. The only difficulties with the Harrison machines have been the breaking of the shank of the pick, usually at the key slot, and the splitting of the forked end of the pick. The former difficulty is being remedied in later machines by enlarging the shank; the splitting of the point is often due to improper forging under a heavy drop hammer, and can usually be checked by a small drill hole heading off the crack.

When labor is abundant and wages are low there seems to be no economy in machine mining, but at other times there are marked advantages, notably in the greater regularity and control of the work, and in its concentration.

Bank wagons.—Whenever it is possible the rehandling of coal is now generally avoided, and the same wagon loaded by the miner is taken to the final shipping point; but when the tramway is very long the wear and tear of the small cars counterbalance the loss and expense of rehandling. The same is true on long and steep gravity planes, especially at mines working thin seams, limiting the size of the cars. When the coal is used wholly or in part for coking the item of loss by breakage disappears, so that on New river the general plan is to use a stock bin at the head of the plane, and to reload the coal into larger cars, known as "monitors," holding from two to four tons.

At most mines the Pittsburgh pattern is followed, and the cars are made without any timber frame, the planks being simply bolted to heavy iron straps. The dimensions are nearly everywhere different, depending greatly on the prejudice of the individual operator so far as regards gauge, diameter of wheels, length and flare of sides, but the height is generally controlled by the thickness of the seam. A fixed axle and loose wheels are generally used.(*a*) This avoids the need of a solid frame, brings the body of the car lower, and is at the same time cheaper. The waste of oil is much greater in lubricating the loose wheels, but this is now being remedied by several patterns of self-oiling box wheels, which carry a supply of oil two to four weeks in regular service, and seem likely to supplant the old patterns. Chilled wheels are generally used, ranging from 10 to 18 inches in diameter. Curved spokes with rounded edges are preferred, to facilitate spragging. Wrought spokes have been tried, but are not regarded with favor.

The use of brakes depends entirely on the grade of the track. When this is generally light no brake is used, but the driver rides on the front bumper of his car and holds it back by pressing with one hand against the mule's rump, using one or more sprags for occasional hills. On steeper grades the driver rides on the hind bumper of the loaded car, which he controls by a brake acting on the wheels of one or both

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a See Dr. Chance's opinion on loose and fixed wheels in anthracite mines, page 119.

sides. More attention is now paid to the use of thick solid bumpers, thus avoiding many accidents, besides increasing the durability of the cars.

The capacity of the mine cars varies from 800 pounds to 2½ long tons, but cars of the latter capacity are built with a timber bed-frame, and use wheels fixed on their axles. Cars of the Pittsburgh pattern are rarely built to carry more than 1 long ton.

Mine tracks.—The room roads are usually laid with oak rails, 2 by 3 inches, or 3 by 4 inches; but when the coal is thin, and the cars must be pushed by hand, T iron rails are taking the place of wooden rails in the rooms. Box ties have been generally abandoned, and the wooden rails are now spiked to the ties. Strap-iron on wood is rarely used. Entry roads are laid with iron rails of from 8 to 24 pounds per yard, according to the size of the car employed, the rails in most common use being 12 and 16-pound.

The gauge varies from 2 feet 6 inches to 4 feet 8½ inches. Where there is ample height a gauge of 3 feet 4 inches or 3 feet 6 inches is commonly taken, but in low seams the gauge is increased, and the cars are very much flared, to obtain large capacity with a limited height.

Hauling.—In thin seams the loaded cars are pushed by the miners themselves, or by special laborers, to the room mouth, where the entry roof is shot down or the bottom taken up, giving sufficient height for a horse or mule. Whenever the coal is as much as 4 feet thick, or that height can be cheaply gotten by a little cutting in the floor or roof, small mules are used to haul directly from the miner. In general, mules are preferred to horses, though the latter are cheaper.

No use is made of inside gravity planes, and there are very few mines in the district where there is sufficient grade. No attempt has yet been made to introduce underground haulage by any of the modifications of the endless rope.

Small locomotives are used at many of the mines for service on outside tramroads, but very few mines in the Kanawha region are so arranged or ventilated as to allow their introduction for inside work, and Hawk's Nest is the only place where one is in use.

Drainage.—Most of the Kanawha mines are so situated that the bulk of the water is disposed of by natural drainage, either through the main entry or by a secondary opening on some side ravine, but still the drainage is often an annoying and expensive matter, not so much on account of the quantity of water as because it collects in scattered basins, from which it must be hauled in water boxes at great expense, and to the injury of the roadway. A few small steam pumps are in use, generally so near the bank mouth that the exhaust steam can be led out in pipes. Siphon pipes are used at many of the mines, and are generally started by means of a common hand pump. No use is made of compressed air, and at present only two steam jets are in operation.

Firedamp.—It is generally said that no firedamp is found in mines working above water level, and it has often been asserted that firedamp is unknown on the Kanawha.

With the exception of some mines on Campbell's creek, which are a few feet below the bed of the stream and are operated by short engine slopes, all the Kanawha and New River mines are above water level, and many of them so high up on the mountain as to have openings on the side valleys of the branch streams. It is true that no serious explosions have ever occurred here, but gas has in several instances accumulated in quantities sufficient to cause slight explosions, scorching the men who have fired it; and cases have also been reported in which the gas escaping from drill holes in an entry has been fired and has continued burning for some time.

The deep depression of the river bed and of the lateral valleys has doubtless aided the escape of gas, and made the present workings safer, but as mining is continued and the openings are extended farther from the outcrop, the probability increases that gas will be found in serious quantities. As yet there are no indications of any amount of firedamp which will not be rendered harmless by even ordinary ventilation, or which will require the substitution of fans for furnaces.

Most of the mines are so damp that the much-disputed question of coal dust, as related to explosions, may be left out of account, but a few of the mines on New river, which are dry and dusty, present features very similar to those of the Pocahontas mine, though on a smaller scale.

Ventilation.—Till quite recently no general attention has been paid to ventilation on the Kanawha. This has been due to the general absence of firedamp and to the possibility of frequent crop openings, as well as to the failure of both operators and miners to realize the importance of the matter. Now that the mines have been extended and pushed farther from the outcrop, the need of increased air is felt, and most of the mines are provided with ventilating furnaces.

The State inspection of mines only commenced in 1883, and it is too soon yet to note any marked results, but it will no doubt be beneficial in stimulating improvement and checking the grosser errors of ignorance and parsimony. Cases are known where in past years headings have been driven entirely too far beyond air, and then, to encourage the miners to persevere still farther, so-called air courses have been started that, when completed, would be of no assistance. The law as now framed is crude and one-sided, bearing principally on the mine owner and giving opportunity for abuse.

Many of the mines are still working by natural ventilation alone, and where they are so situated as to have openings both on the front and on the rear or side of the mountain very little trouble results, especially when the dip of the coal is considerable.

No use is made of ventilating fans, and at many mines there would be difficulty in getting water for steam power where it would be needed, though the power might be transmitted by wire rope from the valley below.

In two cases the attempt has been made to ventilate by compressed air exclusively. Both attempts failed and were soon abandoned. At one mine, where coal-cutting machinery is now employed, the compressed air has been used as an auxiliary to permit driving the headings a longer distance, and with very good results. The air is kept fresh in the immediate vicinity of the working machines, but the volume is too small for practical use in the general ventilation of the mine. It is sometimes stated that the use of compressed air has a bad effect on the slate roof of a coal mine, tending to produce falls, but experience does not seem to justify the assertion.

Gravity planes.—Most of the mines are connected by gravity planes or inclines with their loading works at the railroad or river. Both 4-rail and 3-rail planes are used, and in a few cases 8-rail planes with center tracks of narrow gauge for the safety truck or barney.

The rails are laid either on string timbers or on ties, but the latter are apt to slip and cause the rails to kink where the plane is steep, so that if they cannot be held in place by frequent drift bolts, where outcropping ledges are crossed, light string pieces are sometimes used below the ties to steady them, and blocks are fitted between to brace them apart, the whole being bolted together; this, of course, is only effectual where there is a secure anchorage at the foot of the plane.

Many of the planes are too steep for using a barney to advantage, but where it can be used there is a considerable gain in time, labor, and safety.

Drums and check wheels.—The ordinary drum is from 3 feet to 12 feet in diameter, according to the size of rope and length of plane. The lagging is usually of soft wood. The larger drums are built with wooden segments, and arms secured to cast flanges on an iron shaft. The smaller drums are made with cast-iron spiders. The brake band is often a complete circle, but on large drums is generally halved, and the ends opposite the lever secured as a safeguard in case of breakage, when half the band would still act. The brake is placed either at the middle or at one end of the drum; the former is preferred.

Drums are generally placed overhead, but where a barney is used they are sunk below the level of the tracks.

In order that both ropes may lead from the same level, two drums are sometimes used, connected by cog gearing, to work in opposite directions. They do not meet with favor, on the ground of increased cost, greater space required, and liability to accident.

On ordinary drums two ropes are required, winding and unwinding the length of the plane, but by the use of friction sheaves only a single rope is needed. These are cast sheaves filled between their flanges with end-wood blocks to receive the rope, which takes a sufficient number of turns to prevent slipping. They work in pairs, revolving horizontally, and are controlled either by a single brake or by one on each sheave. There is economy in the space required and in the length of rope used, but the wear of the rope is heavy from the number of bends, apart from the size of the sheaves, which are usually limited in diameter to the distance between the track centers. In case the rope breaks, both cars are likely to be destroyed, and when there is any unequal wear of the end-wood blocks filling the sheaves, their action is liable to become that of an eccentric, bringing an excessive strain on the shafts and rope.

Scales and screens.—The arrangement of scales and screens differs widely for the different classes of coal. On New river the coal is all paid for as run of mine, and is weighed before dumping. It is then either shipped without screening, or if there are coke ovens to be supplied it is passed over screens of varying width of opening, according to the proportion of small coal needed at the time for coking.

At the splint and gas coal mines the miners are paid on the basis of lump coal, and the coal is not weighed till it has been screened. Gas coal is dumped over one-half-inch to five-eighths-inch screens, and the harder splint over screens of 1¼-inch to 2-inch. The coal passing through this coarse screen is again divided into nut and slack by a finer screen of one-half-inch to three-quarters-inch.

Rolled iron screen bars of tapering section are generally used, but improved steel screens with thinner bars are being introduced at new works. No use is made of drum screens.

Coal is estimated at the mines either by the long ton of 2,240 pounds, or by the weighed bushel of 80 pounds. Formerly the gauged bushel of 2,688 cubic inches was used, but scales have now been introduced at nearly every mine, and prove much more satisfactory.

Stock bins and loading arrangements.—Stock bins were formerly used in loading splint coal on the railroad, and they served to equalize the work when the supply of cars was irregular, but the loss from breakage of coal and the extra expense of handling were so great that they have all been abandoned. Now the coal falls from the screen directly into the railroad car, and is there weighed by means of track scales, or else is weighed in a section of the loading chute, known as the weigh basket, and suspended from a scale platform at the landing floor. The outer end of the weigh basket is often suspended from a counterweighted drum, resting on the scale platform and controlled by a brake. The object is to lessen the force of the coal as it comes from the screen, and then to discharge it easily from the weigh basket into the car. Where the tipple is high, the weigh basket may be suspended from two drums and lowered bodily, as described for river tipples.

On New river, where the fine coal is coked, breakage is no objection, and large stock bins are used to advantage. At some of the coke works long sheet-iron pipes have been introduced, through which the coal is dumped, striking a cast-iron block below for the express purpose of breaking it fine. This takes the place of a mechanical crusher.

The Kanawha river is subject to heavy floods and very rapid changes of level. Loading of river barges is carried on from low-water to about a 15-foot stage, when work is usually suspended. The river is liable at any time to rise 25 feet, and in extreme floods 40 feet.

Formerly the incline track was extended into the river and secured to a timber crib filled with rock at extreme low-water level. A movable carriage or slide was used, forming a horizontal extension of the incline, and provided with outriggers or timbers, projecting over the barges into which the coal was dumped. These slides were very heavy, and required frequent moving to adjust them to the varying stages of the river. They are now replaced by high tipples or dumping platforms, built on solid cribs or on piles, and rising 40 to 75 feet above low water. The coal is usually screened at the river, and the slack and nut are led by chutes to their respective barges. The lump coal at the best tipples drops from the screen into the weigh basket, which is suspended at the center by wire ropes leading to a brake drum, and connected with counterweights. The brake drum, with the weigh basket, counterweights, guide arms, stop ropes, and all their connections, are carried on a scale platform. After the coal is weighed the basket is lowered, and may be dumped by means of stop chains from either end; or, if provided with center hinges the stop chains may all be tightened alike, when the basket will open in the center and drop the coal. The object of this is to deposit the coal regularly and lightly, so as to avoid straining the barge, and to make the leveling of the coal easier.

If the coal has been transferred from the mine wagons to larger cars, and already weighed before reaching the river, it is either handled by a drop basket similar to the weigh basket, or else the loaded car, resting on a movable section of the track, is lowered into the barge and there dumped.

When coal shipped in barges is to be sold on the market, it is carefully leveled for gauging, as river sales are not made by weight, but by the measured bushel of 2,688 cubic inches.

The work of improving the Kanawha river is now being carried on by the general Government, and slack-water navigation has already been secured for 18 miles by one permanent and two movable dams. The two dams now under construction will extend the system 15 miles. The river is very rapid in time of flood, and breakwaters are built to protect the tipples and barges against floating drift and ice. Heavy ice is sometimes formed, and much damage has been done at times by gorges. It is hoped that the fixed dams on the upper part of the Kanawha will be a help in the future by holding back the ice for a time. and then breaking it as it passes over.

Barges.—The barges used for river loading are of the Pittsburgh pattern, but are generally made with lower sides. They are 130 feet long by 25 feet wide, costing $1,000 to $1,200 each, and having a capacity of 10,000 bushels of coal when drawing 5 feet. Skeleton barges are also used of the same size and similar in construction, except that their sides are of framework covered with plank, in place of being built of solid timber.

The principal river market for Kanawha coal is Cincinnati, but some is taken as far as Louisville, and a few of the large 20,000-bushel flat-boats have been loaded for the New Orleans trade as an experiment.

Stern-wheel tow-boats are used exclusively, and they can handle from two to twelve barges on the Kanawha, according to the stage of water, but increase the size of their tows on the Ohio, taking twenty or more barges.

Washing and crushing machinery.—Coal-washing machinery has not been used in the district, and the only crusher is one at Hawk's Nest Coke Works, unless the arrangement of rapid discharge through an iron pipe can be called a crusher.

Coke making.(*a*)—The New River slack coal is suited for direct coking, and the coke made at those mines has met with much favor in market. The splint slack does not coke so well, and in nearly all cases is mixed with slate and bone coal or "nigger head;" but as most of the splint mines are within the limits of river navigation, the slack finds a market as a cheap fuel for steamboats and for factories. The slack from the gas coal mines has not been coked with success, but after washing would no doubt make a very good coke. At present these mines are above the limit of river navigation, and the distance by rail to any large manufacturing district is so great that the market is limited and their slack is often a source of expense.

Coke is successfully made at Eagle and at Hawk's Nest from coals belonging to the middle series, and experiments show that there are several seams which, locally at least, will make very good coke.

Beehive ovens of the ordinary pattern are the only ones used except at Hawk's Nest, where a block of eighty Soldenhof ovens has been built. They are a modification of the Belgian oven, designed to quicken the coking process by the combustion of gas in the cellular walls and underlying flues of the ovens. The coke is discharged by a steam ram at the conclusion of the process, and is quenched by the use of water on the yard instead of in the oven.

The location of the Hawk's Nest ovens was a very expensive one, and the firebrick used in their construction proved inferior. The many repairs required on starting the ovens were a great injury to the character of the coke in a process requiring regular work, and as these repairs have been continued up to the present, it is impossible to make a fair comparison between the two systems.

The Soldenhof ovens give a coke with shorter fiber and generally less luster than the beehive ovens. They are more compact and require less labor, but their first cost is very heavy, and they require more repairs. They have not yet proved to possess any advantage over the beehive ovens.

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a See also pages 207–213.

THE MANUFACTURE OF COKE.

By Joseph D. Weeks.

In this report the word "coke" is used in a restricted sense, including only that coke made from bituminous coal in ovens, pits, ricks, or "on the ground," and which, for convenience, may be termed "oven coke." "Gas coke," or that which is a residual product of the manufacture of gas, is not reported upon. The unit of quantity is the short ton of 2,000 pounds.

Coal fields and coking coals of the United States.—The coal used in the manufacture of coke in the United States in 1884 came chiefly from four of the great coal basins or coal fields of the country, the Appalachian, the Illinois, the Missouri, and the El Moro (Colorado). By far the largest part was derived from the measures of the great Appalachian fields; only about 3 per cent. of the total coming from the Illinois, Missouri, and Colorado basins. In addition to these sources of supply detached fields furnish a very small percentage.

The Appalachian basin is the most important, though by no means the largest in area, of the coal fields of America. Beginning near the northern boundary of Pennsylvania, it extends for a distance of over 750 miles in a southwesterly direction, following the western line of the Alleghany mountains, with a course nearly parallel to the Atlantic coast line, through western Pennsylvania, West Virginia, Kentucky, Tennessee, Georgia, and Alabama, to Tuscaloosa, Alabama, where it ends. The average breadth of the field is from 80 to 90 miles, the area being fully 70,000 square miles. The eastern escarpment of the Alleghany mountains formed, and still forms, the eastern border of this basin; while the great Cincinnati anticlinal hems it in on the west and separates it from the measures of the Illinois basin. The eastern line of this field is comparatively irregular, the basin being quite broad in its northern area, contracting through Tennessee and northern Alabama, and expanding considerably at its termination in Alabama, though it is there by no means so broad as in Pennsylvania, Ohio, and West Virginia.

In the northern part of this basin the coal is found in isolated patches, the chief of which are the Blossburg, McIntyre, and Barclay. Between the eastern edge and the ocean other detached fields are found, such as the anthracite coal fields of northeastern Pennsylvania, the Broad Top semi-bituminous coal field of middle Pennsylvania, and the Cumberland coal basin of Maryland. These patches are all that have been left by the denuding agencies which have swept away so much of the Devonian and Silurian rocks and cut so deeply and sharply, and at the same time so destructively, into the measures in this belt of country.

Along nearly the entire length of this field, from Blossburg, Pennsylvania, on the north, to Birmingham, Alabama, on the south, the coke industry has been established. The ovens, following the zone of best coking coal, are generally found near the eastern limits of the field, hugging the mountains, the coal in the middle or western part of the basin being, as a rule, not so well adapted to coking as that in the eastern. It is also true that the coal in the upper portion of this field, as in Connellsville and on the New river, produces better coke than that of the southern in Tennessee and Alabama.

The greatest development in the manufacture of coke is in the Connellsville region of western Pennsylvania, a small trough 50 or 60 miles long by 3 miles wide. The Connellsville coke is regarded as the typical coke of this country, as the Durham is in England. Some other sections in this field may produce a coke equal in purity to the Connellsville, but as a blast-furnace fuel, which is the use to which most coke is put, it is so well adapted, its use is so extensive, and its characteristics so well known, that it fully deserves the designation "typical." Coke is made at other points in Pennsylvania, especially in the Alleghany Mountain, Alleghany Valley, Blossburg, and Broad Top regions, in the Ligonier valley, and near Pittsburgh. None of these cokes equal the Connellsville. In some cases they are lower in ash but inferior in physical structure, while in others washing is necessary to produce a fuel for blast-furnace use.

In West Virginia the New River coal furnishes the most and also the best coke. Analysis shows it to be lower in ash than the Connellsville, and its producers assert that it is fully equal to it as a blast-furnace fuel; but this is by no means conceded. In the northern part of the State, in Tyler, Marion, Preston, and Harrison counties the coking industry is assuming some importance. Quite a number of ovens are already erected, and others building. The coke is a fair fuel.

In Ohio most of the coals are coking coals, but the deposits are much thinner than in either Pennsylvania or West Virginia, and generally, though not always, contain an objectionable amount of sulphur. The coals are coked only to a limited extent, and the manufacture of coke is not increasing as rapidly as in Pennsylvania, West Virginia, and Alabama.

In Tennessee the Sewanee seam furnishes most of the coke, while in Alabama coals from both the Warrior (chiefly from the Pratt seam) and the Cahaba fields were coked. The extreme eastern outcrop of the Appalachian basin cuts the northwestern corner of the State of Georgia, furnishing a small patch of coking coal, from which some coke was made in the years covered by this report.

The Coal Measures of the Illinois basin very nearly equal in area those of the Appalachian basin, covering about 47,188 square miles(*a*),

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a "Statistical Atlas of the United States," page 12. Some authorities make this 68,000.

but they by no means equal the latter in the character of their coking coal. This basin occupies the larger part of the State of Illinois, the southwestern part of Indiana, and the western part of Kentucky. Its eastern limit is the rocks of the Cincinnati axis, which separate it from the Appalachian basin; while its western margin is formed by the bed of the Mississippi river, which has been excavated through it and separates it from the Missouri basin. The beds of coal in the Illinois field are not as thick as in either the Appalachian or the Missouri basin, though their number is about the same as in the former. "The coals themselves are more apt to be impure[a]," being high in sulphur and ash. This is not uniformly the case, however, as will be evident from an inspection of the analysis of the Big Muddy and Cartersville coals of southwestern Illinois. The coals of the northern part of this basin in Illinois are as a rule too sulphurous to make good coke, but in the southwestern part of the State there are several small deposits of quite pure coal, which, although dry burning, makes a very good coke when crushed, washed, and charged wet. The character of the coals of this basin and the difficulty of adapting them to the manufacture of coke are shown in the fact that but 8,600 tons of coke were made from them in the census year.

In Indiana the coals of the "eastern zone" of Professor Cox's reports, or the Lower Measures, are non-coking, being the well known block coal of the State, which can be used raw in smelting iron. The "western zone," or Upper Measures, which are much more extensive than the Lower, contain deposits of good coking coal generally; however, so far as they have been tried for making coke, high in ash and sulphur.

The coal of that portion of this field lying in Kentucky, like that part of the Appalachian field lying in the same State, has not been utilized as yet to any extent for the manufacture of coke.

The Missouri basin is the largest in area of all the coal fields of the United States, containing, it is estimated, 84,343 square miles. It extends through Iowa, Missouri, Nebraska, Kansas, Arkansas, and Indian Territory. The measures are thinner and contain fewer beds than the Appalachian. But little coke was made from the coals of this basin. At one place in the Indian Territory and in the Cherokee region of Kansas some little is made to utilize slack from the mines.

But little is known of the extent of the coking coal in what I have termed, for want of a better name, the El Moro (Colorado) basin, which may be regarded as including the coal mines of New Mexico. From the coal mines of the Trinidad region, which are the highest above the sea level worked in the country, considerable coke is made for smelting purposes. At Crested Butte it is made for the Utah smelters, and in other portions of the basin coke in small amounts, usually high in ash, is produced for the local smelting works.

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[a] "Statistical Atlas of the United States," page 13.

Coke was also made in small amounts from the coals of Montana and Washington, the latter being the only coke made on the Pacific coast. Some coke has been made in Utah, but none for the past two years.

Statistics of coke in the United States.—In the following table are consolidated the statistics of coking in the United States from 1880 to 1884. From this table it appears that the number of establishments making coke in the United States increased from 186 in 1880 to 250 in 1884, an increase of a little over 34 per cent. The number of ovens built increased from 12,372 in 1880, to 19,557 in 1884, an increase of 58 per cent. The amount of coal used to make coke increased from 5,237,741 short tons in 1880 to 7,951,974 tons in 1884, an increase of nearly 52 per cent. The coke produced increased from 3,338,300 short tons in 1880 to 4,873,805 tons in 1884, an increase of about 46 per cent. It will be noticed that the coal consumed and coke made in 1883 were both greater than in 1884. The total value of coke at the ovens increased from $6,631,267 to $7,242,878, an increase of about 9.2 per cent. The value of the coke produced in each of the years 1881, 1882, and 1883, however, was greater than in 1884. The value of the coke at ovens decreased from $1.99 in 1880 to $1.49 in 1884, a decrease of about 25 per cent.

Statistics of the manufacture of coke in the United States, 1880 *to* 1884, *inclusive.*

	1880.	1881.	1882.	1883.	1884.
Number of establishments	186	197	215	231	250
Ovens built	12, 372	14, 119	16, 356	18, 304	19, 557
Ovens building	1, 159	1, 005	712	407	812
Coal used, short tons	5, 237, 741	6, 546, 662	7, 577, 648	8, 516, 670	7, 951, 974
Coke produced, short tons	3, 338, 300	4, 113, 760	4, 793, 321	5, 464, 721	4, 873, 805
Total value coke at ovens	$6, 631, 267	$7, 725, 175	$8, 462, 167	$8, 121, 607	$7, 242, 878
Value coke at ovens, per ton	$1. 99	$1. 88	$1. 77	$1. 49	$1. 49
Yield of coal in coke, per cent	63	63	63	64	61

Production of coke in the census years 1850–1880.—Until the census of 1880 no thorough and systematic attempt had been made to collect the statistics of the manufacture of coke in this country. It is therefore impossible to even estimate what was the production prior to 1880, except during the census years 1850, 1860, and 1870. Coal and coke are frequently reported together in a way most provoking to the collector of statistics, coke being regarded simply as a form of coal. While it is possible to ascertain the production of individual works and to estimate that of some sections, no satisfactory statement of the production for the years before 1880, except as noted, can be obtained. In the following table is given a summary of the totals of the most important items covered by the census of 1880, compared with similar results obtained at the censuses of 1870, 1860, and 1850. These figures prior to 1880 must be regarded only as approximates.

Census statistics of coke.

	1880.	1870.	1860.	1850.
Number of establishments	149	25	21	4
Number of persons employed	3, 142	528	198	14
Amount of capital, real and personal	$5, 545, 058	$1, 201, 043	$62, 300	$3, 700
Wages paid	1, 198, 654	288, 695	61, 368	3, 444
Value of all materials used, including coal	2, 995, 441	615, 268	73, 552	6, 038
Value of coke produced	5, 359, 489	1, 132, 386	189, 844	15, 250

This table indicates a most remarkable growth. It must be remembered that coke is both bulky and low priced, and in proportion to its weight it is one of the lowest, if not the lowest, priced of any manufactured article. During the census year 1880 the average value of a railroad carload of coke, containing from 12 to 14 tons, was from $24 to $28 at the ovens. But little of the coke is used where made, the nearest important point of consumption to the Connellsville region (which produced more than 68 per cent. of all the coke made) being Pittsburgh, about 60 miles distant, while hundreds of thousands of tons are carried to points much farther away. The growth of the industry in these years, then, means a growth where the margins of profit must be small and the tonnage handled immense, and the difficulties in the way of its growth, as is always the case with low-priced, heavy articles that must be transported long distances to market, well-nigh insurmountable. To organize and operate effectively the railroad service in connection with this heavy increase of traffic has been of itself no small undertaking. All things considered, the development of the manufacture of coke must be regarded as one of the most marked achievements in our industrial progress.

Total number of coke works in the United States.—In the following table is given the total number of establishments manufacturing coke in the United States for each year from 1880 to 1884. Each separate coke works with its ovens and other plant is classified as an establishment. In many instances it was found that an individual or firm operated several works, sometimes contiguous, in other cases widely separated, but, notwithstanding this joint ownership, each works is regarded as an establishment, and is so classified. It has been difficult, however, in some cases, to determine whether works operated by the same owner on adjoining properties should be classified as one or more establishments. In such cases we have taken the judgment of the owner. The number of works, therefore, and the number of separate firms or owners are not the same.

The number of establishments in the country for the years since 1850, for which there are any returns, was as follows:

Years.	Number.	Years.	Number.
1850 (census year)	4	1881, December 31	197
1860 (census year)	21	1882, December 31	215
1870 (census year)	25	1883, December 31	231
1880 (census year)	149	1884, December 31	250
1880, December 31	186		

In the following table is given the number of these establishments by States. It will be noticed that in 1884, of the 250 works in the United States, 145, or 58.6 per cent., were in Pennsylvania; 27, or 10.8 per cent., in West Virginia; 19, or 7.6 per cent., in Ohio; and 13, or 5.2 per cent., in Tennessee. In each of the other States the number was less than 10.

Number of establishments in the United States manufacturing coke in the years from 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	4	4	5	6	8
Colorado	1	2	5	7	8
Georgia	1	1	1	1	1
Illinois	6	6	7	7	9
Indiana	2	2	2	2	2
Indian Territory	1	1	1	1	1
Kansas	2	3	3	4	4
Kentucky	5	5	5	5	5
Montana	0	0	0	1	3
New Mexico	0	0	2	2	2
Ohio	15	15	16	18	19
Pennsylvania	124	132	137	140	145
Tennessee	6	6	8	11	13
Utah	1	1	1	1	1
Virginia	0	0	0	1	1
Washington	0	0	0	0	1
West Virginia	18	19	22	24	27
Total	186	197	215	231	250

The number of establishments is the number December 31 of each year.

Total number of ovens built in the United States.—In the following table is given the total number of ovens built in the United States and also the number in each State, December 31, for each of the years from 1880 to 1884. In addition to that made in ovens, some coke was made in pits, but as the number of pits varies greatly, depending upon the demand, no attempt has been made to state their total number.

In the years covered by the report the number of ovens has increased from 12,372 in 1880 to 19,557 in 1884, or 58 per cent. The States having more than a thousand ovens each in 1884 are Pennsylvania, with 14,285, or 73 per cent.; Tennessee, with 1,105, or 5.7 per cent.; and West Virginia, with 1,005, or 5.1 per cent. Alabama had 976 ovens, or 5 per cent. The greatest increase in the time covered by the tables is in Alabama, there being in that State in 1880 316 ovens and in 1884 976 ovens, an increase of 209 per cent. The increase in Pennsylvania has been from 9,501 to 14,285, or 50 per cent.; in Tennessee, from 656 to 1,105, or 68 per cent.; in West Virginia, from 631 to 1,005, or 59 per cent. The number of ovens in Colorado and Georgia has increased a little over 100 per cent.; in Illinois a little less than 100 per cent.; while Virginia, which had no ovens in 1880, now has 200. Montana and New Mexico, which also had no ovens in 1880, now have ovens. Kansas, which had 6 ovens in 1880, now has 23. In but one State has there been a decrease in the number of ovens, Indiana, but no coke was made in this State in the years covered by the report.

Number of coke ovens in the United States on December 31, of each of the years from 1880 to 1884, by States and Territories.

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	316	416	536	767	976
Colorado	200	267	344	352	409
Georgia	140	180	220	264	300
Illinois	176	176	304	316	325
Indiana	45	45	37	37	37
Indian Territory	20	20	20	20	20
Kansas	6	15	20	23	23
Kentucky	45	45	45	45	45
Montana	0	0	0	2	5
New Mexico	0	0	0	12	70
Ohio	616	641	647	682	732
Pennsylvania	9, 501	10, 881	12, 424	13, 610	14, 285
Tennessee	656	724	861	992	1, 105
Utah	20	20	20	20	20
Virginia	0	0	0	200	200
Washington	0	0	0	0	0
West Virginia	631	689	878	962	1, 005
Total	12, 372	14, 119	16, 356	18, 304	19, 557

Number of ovens building in the United States.—In the following table is given the number of ovens that were actually in course of construction at the close of each of the years from 1880 to 1884. There is no attempt in this to show the increase in the number of ovens each year. It is simply an indication as to the progress of building at the close of each year.

Number of coke ovens building in the United States at the close of each of the years from 1880 to 1884, by States and Territories.

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	100	120	0	122	242
Colorado	50	0	0	0	24
Georgia	40	40	44	36	0
Illinois	0	0	0	0	0
Indiana	0	0	0	0	0
Indian Territory	0	0	0	0	0
Kansas	0	0	0	0	0
Kentucky	0	0	0	0	0
Montana	0	0	0	0	12
New Mexico	0	0	12	28	0
Ohio	25	0	0	0	0
Pennsylvania	836	761	642	211	232
Tennessee	68	84	14	10	175
Utah	0	0	0	0	0
Virginia	0	0	0	0	0
Washington	0	0	0	0	0
West Virginia	40	0	0	0	127
Total	1, 159	1, 005	712	407	812

Amount of coal coked.—In the following table is given the total number of tons of coal made into coke in the United States for the several years covered by this report. In this is included all the coal coked, whether charged into the ovens as "run of the mine" or "slack." A large proportion of the coal coked is "run of the mine," the coal being only mined for the purpose of being made into coke. This is especially true of the Connellsville and Alleghany Mountain districts in Pennsylvania, the New River district in West Virginia, and the Warrior district in Alabama, as well as several others. On the other hand, a large amount of the coking, as will appear from the statement made in connection with the industry in the different districts, is for the purpose of utilizing the slack coal produced in mining. This is true of the Pittsburgh district in Pennsylvania, as well as of many of the localities producing but a small amount of coke. It was not found practicable however, as suggested above, to separate between the coal which was used as "run of the mine" and that which was used as "slack."

There was a steady and marked increase in the amount of coal used for the production of coke from 1850 to 1883, when it reached the maximum of 8,516,670 tons; in 1884 there was a decline from this to 7,951,974 tons.

Amount of coal used in the manufacture of coke in the United States from 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
Alabama	106, 283	184, 881	261, 839	359, 699	413, 184
Colorado	51, 891	97, 508	180, 549	224, 089	181, 968
Georgia	63, 402	68, 960	77, 670	111, 687	132, 113
Illinois	31, 240	35, 240	25, 270	31, 370	30, 168
Indiana	0	0	0	0	0
Indian Territory	2, 494	2, 852	3, 266	4, 150	3, 084
Kansas	4, 800	8, 800	9, 200	13, 400	11, 500
Kentucky	7, 206	7, 406	6, 906	8, 437	3, 451
Montana	0	0	0	0	165
New Mexico	0	0	1, 500	6, 941	29, 990
Ohio	172, 453	201, 145	181, 577	152, 502	108, 164
Pennsylvania	4, 347, 558	5, 393, 503	6, 149, 179	6, 823, 275	6, 204, 604
Tennessee	217, 656	241, 644	313, 537	330, 961	348, 295
Utah	2, 000	0	500	0	0
Virginia	0	0	0	39, 000	99, 000
Washington	0	0	0	0	700
West Virginia	230, 758	304, 823	366, 653	411, 159	385, 588
Wyoming	0	0	0	0	0
Total	5, 237, 741	6, 546, 662	7, 577, 646	8, 516, 670	7, 951, 974

Amount of coke made.—The maximum production of coke in the United States was reached in 1883, 5,464,721 short tons being made in this year. This was an increase over 1880, when 3,338,300 tons were made, of 2,126,421 tons, or an increase on the make of 1880 of $63\frac{2}{3}$ per cent. In 1884 the production declined, chiefly owing to the reduced demand for coke for blast furnaces, to 4,873,805 tons.

As has been the case ever since coking became an industry in this country, Pennsylvania is the chief producer of coke, its production being 3,822,128 tons in 1884, or 78.4 per cent. of the total. The second State in production is Alabama, its production being 244,009 tons, or 5 per cent. of the whole. The third State is West Virginia, producing 233,472 tons, or 4.6 per cent. of the whole. The fourth State is Tennessee, producing 219,723 tons, or 4.5 per cent. of the whole. The fifth State is Colorado, producing 115,719 tons, or 2.4 per cent. of the whole. Georgia ranked sixth, Virginia seventh, and Ohio eighth. The following table will show the relative rank of the States, measured by production, in the census year and in 1884:

Rank of the States and Territories in production of coke in 1880 *and* 1884.

States and Territories.	1884.	1880.
Pennsylvania	1	1
Alabama	2	6
West Virginia	3	3
Tennessee	4	4
Colorado	5	7
Georgia	6	5
Virginia	7	0
Ohio	8	2
New Mexico	9	0
Illinois	10	8
Kansas	11	0
Kentucky	12	0
Indian Territory	13	9
Washington	14	0
Montana	15	0

The changes in this will be noted. Ohio drops from the second place to the eighth, and Alabama, which occupied the sixth place, takes the second. Pennsylvania, West Virginia, and Tennessee occupy the same relative places. Indiana, which produced coke in the census year, drops out of the list, while Virginia, New Mexico, Kansas, Kentucky, Washington, and Montana, which produced no coke in the census year, appear as producers in 1884.

Amount of coke produced in the United States 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
Alabama	60, 781	109 033	152, 940	217, 531	244, 009
Colorado	25, 568	48, 587	102, 105	133, 997	115, 719
Georgia	38, 041	41, 376	46, 602	67, 012	79, 268
Illinois	12, 700	14, 800	11, 400	13, 400	13, 095
Indiana	0	0	0	0	0
Indian Territory	1, 546	1, 768	2, 025	2, 573	1, 912
Kansas	3, 070	5, 670	6, 080	8, 430	7, 190
Kentucky	4, 250	4, 370	4, 070	5, 025	2, 223
Montana	0	0	0	0	75
New Mexico	0	0	1, 000	3, 905	18, 282
Ohio	100, 596	119, 469	103, 722	87, 834	62, 709
Pennsylvania	2, 821, 384	3, 437, 708	3, 945, 034	4, 438, 464	3, 822, 128
Tennessee	130, 609	143, 853	187, 695	203, 691	219, 723
Utah	1, 000	0	250	0	0
Virginia	0	0	0	25, 340	63, 600
Washington	0	0	0	0	400
West Virginia	138, 755	187, 126	230, 398	257, 519	223, 472
Total	3, 338, 300	4, 113, 760	4, 793, 321	5, 464, 721	4, 873, 805

Value and average selling price of coke.—In the following tables are given the total value of the coke produced and its average selling price, for each of the years from 1880 to 1884. The maximum of total value was reached in 1882, while the maximum of value per ton was in 1880. The total value is to be regarded as the total selling price at the ovens, and the average value is the average selling price at the ovens. Coke is rarely stocked at the place of manufacture, but when drawn from the ovens, is loaded directly into cars and sent to the place of consumption, where any surplus is stored. In regard to this total value and average value it is to be noted that in many cases they are estimates. Much of the coke made in the United States is made by the proprietors of blast furnaces for consumption in their own furnaces; hence they can only estimate what the value of the coke would be. In some cases this value is estimated at what other coke of the same grade would cost delivered at the furnace; in other cases the value is estimated at the actual cost of the coke at the furnace, plus a small percentage for profit on the coking operations, while in other cases the value is estimated at the actual cost of the coke. The following table gives the total value of the coke of the United States, and also the total value by States:

Total value at the ovens of the coke made in the United States in the years from 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	$183, 063	$326, 819	$425, 940	$598, 473	$609, 185
Colorado	145, 226	267, 156	476, 665	584, 578	409, 930
Georgia	81, 789	88, 753	100, 194	147, 166	169, 192
Illinois	41, 950	45, 850	29, 050	28, 20[illegible]	25, 639
Indiana	0	0	0	0	0
Indian Territory	4, 638	5, 304	6, 075	7, 719	5, 736
Kansas	6, 000	10, 200	11, 460	16, 560	14, 580
Kentucky	12, 250	12, 630	11, 530	14, 425	8, 760
Montana	0	0	0	0	900
New Mexico	0	0	6, 000	21, 478	91, 410
Ohio	255, 905	297, 728	266, 113	225, 660	156, 294
Pennsylvania	5, 255, 042	5, 898, 579	6, 133, 698	5, 410, 387	4, 783, 230
Tennessee	316, 607	342, 585	472, 505	459, 126	428, 870
Utah	10, 000	0	2, 500	0	0
Virginia	0	0	0	44, 345	111, 300
Washington	0	0	0	0	1, 900
West Virginia	318, 797	429, 571	520, 437	563, 490	425, 952
Total	6, 631, 267	7, 725, 175	8, 462, 167	8, 121, 607	7, 242, 878

In the table of average values given below it will be noted that there is a constant decline in average value from 1880 to 1883, while the average value in 1884 was the same as in 1883. This arises from the fact that early in 1884 a pool was formed by the majority of the coke manufacturers in the Connellsville region for the purpose of advancing the price of coke, which had declined to 90 cents a ton for furnace coke and $1.10 for foundry coke. These were the prices from January 1, 1884, to April 1 of the same year. At the latter date the pool went into operation, when the prices were advanced to $1.10 for furnace coke and $1.25 for foundry coke. The highest average price of coke in any State in 1884 was $12 in Montana; the lowest, $1.19 in West Virginia, and the next lowest, $1.25 in Pennsylvania.

Average value per short ton at the ovens of the coke made in the United States in the years from 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	$3. 01	$3. 00	$2. 79	$2. 75	$2. 50
Colorado	5. 68	5. 29	4. 67	4. 36	3. 45
Georgia	2. 15	2. 15	2. 15	2. 20	2. 13
Illinois	3. 30	3. 10	2. 55	2. 10	1. 96
Indiana	0	0	0	0	0
Indian Territory	3. 00	3. 00	3. 00	3. 00	3. 00
Kansas	1. 95	1. 80	1. 70	1. 96	2. 02
Kentucky	2. 88	2. 89	2. 83	2. 87	3. 94
Montana	0	0	0	0	12. 00
New Mexico	0	0	6. 00	5. 50	5. 00
Ohio	2. 54	2. 49	2. 57	2. 57	2. 49
Pennsylvania	1. 86	1. 70	1. 55	1. 22	1. 25
Tennessee	2. 42	2. 33	2. 52	2. 25	1. 95
Utah	10. 00	0	10. 00	0	0
Virginia	0	0	0	1. 75	1. 75
Washington	0	0	0	0	4. 75
West Virginia	2. 30	2. 30	2. 26	2. 19	1. 19
Total average	1. 99	1. 88	1. 77	1. 49	1. 49

Yield of coal in coke.—The table given below shows the average yield in coke of the coal coked in the several States and in the United States for the years from 1880 to 1884. The years 1880, 1881, and 1882 show a practically uniform yield of about 63 per cent. The yield for 1883 is given at 64 per cent. for the whole United States, while the yield for 1884 drops to 61 per cent. As was stated to be the case in connection with the figures for total value and average value, many of the percentages of this table are estimates. A great deal of the coal coked, as has already been stated, is slack, which in many cases is charged into the ovens without weighing. In such cases only a rough estimate of the amount so charged could be given. It will be noted in connection with the figures from Pennsylvania that they drop suddenly from 65 per cent. in 1883 to 62 per cent in 1884. This is manifestly an error, and though the 62 per cent. is the result shown by the reports made, there is no doubt that the figures should be increased at least to 64 per cent. It is probable also that the figures of yield in West Virginia should be increased all the way through. It, however, can be said in regard to these, as it is of the Pennsylvania figures, that they are the results obtained from the reports forwarded and include the yield in the whole States, not in the best districts alone.

Percentage yield of coal in the manufacture of coke in the United States in the years 1880 *to* 1884, *by States and Territories.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Alabama	57	59	58	60	60
Colorado	49	50	57	60	64
Georgia	60	60	60	60	60
Illinois	41	42	45	43	43
Indiana	0	0	0	0	0
Indian Territory	62	62	62	62	62
Kansas	64	64.4	65	62.9	62¼
Kentucky	60	60	59	60	64
Montana	0	0	0	0	46
New Mexico	0	0	66⅔	57¼	57½
Ohio	58	59	57	58	58
Pennsylvania	65	64	64	65	62
Tennessee	60	60	60	62	63
Utah	50	0	50	0	0
Virginia	0	0	0	64½	64¼
Washington	0	0	0	0	57½
West Virginia	60	61	63	63	62
Total average	63	63	63	64	61

ALABAMA.

The growth of the coke industry in Alabama since the close of the census year, May 31, 1880, has been most marked. At that time there were but two hundred and sixteen coke ovens built in the State. At the close of 1884 there were nine hundred and seventy-six, and some coke was made on the ground. There are also at least four coke works building at the present time. The production of coke for the twelve months of the census year was 42,035 tons. In the twelve months of 1884 the total output was 244,007 tons, an increase of 480 per cent. in the four years and a half. The cause of this rapid growth has been the development of the blast furnace industry in the vicinity of Birmingham, and the change from charcoal as a furnace fuel to coke.

There are in Alabama, in which State the great Appalachian basin reaches its extreme southern development, three important coal fields or basins, named from the streams which drain them, the Coosa, containing 100 square miles; the Cahaba, with some 230 square miles, and the Warrior, with some 4,700 square miles. Recent investigations indicate that there are six fields, but three of these are of little value economically. At present coking operations are confined chiefly to the Warrior field. There are 100 ovens at Helena in the Cahaba field, but no coke has been made in them for two years until since the 1st of January, 1885. The coke was too high in ash and in other respects an inferior fuel for iron making, and has been superseded by the coke made from the Pratt seam. It is, however, used in heating the retorts at the New Orleans gas works, where water gas is made. At another works in this district some coke for domestic use was made on the ground, and more ovens are building at Helena. It is also reported that two hundred ovens are to be built the present year in the Broken Arrow region, Coosa field, but at present but little coke is made from either the Cahaba or Coosa coals.

Five veins are worked in the Warrior field, and of these four have been tested and found to yield coking coal. Of these four seams what is known as the Pratt seam, or, as it is sometimes called, the Brown or Coketon, is economically the most important of the Alabama coals. It shows a thickness of from 4 feet 6 inches to 6 feet, and has only one shale parting, with about 4 feet of coal in the upper bench. From this seam most of the coke made in Alabama is produced, chiefly from the coal of the Pratt mines in Jefferson county. The Pratt Coal and Iron Company cokes a large amount of coal in its own ovens at the Pratt mines, and sells still larger quantities to other oven proprietors to be coked. The Mary Pratt and Eureka furnaces obtain their supplies of coke from the Pratt company. The Sloss and Alice furnaces buy coal and coke it. The Woodward Iron Company at Wheeling mine the coal for their ovens from their own mines near their furnaces, while the Milner Coal and Railroad Company at New Castle have six ovens in which they coke the slack from their mines. At both Wheeling and New Castle the seam mined is said to be the Pratt. The coke from this seam, taken from different points, gives from 85.80 per cent. to 93.01 per cent. fixed carbon; 6.83 to 15.06 per cent. of ash, and 0.575 per cent. to 1.08 per cent. surphur.

As described by Professor Killebrew, the coal at the Pratt mines is hard and semilustrous, laminated, and breaks into long, broad masses across the plane of lamination. The seam at Pratt is 4½ feet thick.

In addition to the five works mentioned above that are making coke in the Warrior field, two others have commenced the erection of ovens since January 1. This will make the number of works built and building in Alabama, April 1, 1885, by districts, as follows:

Warrior field	7
Cahaba field	3
Coosa field	1

The following are analyses of Alabama coals and cokes:

Analyses of the coals and cokes of the Warrior field, Alabama.

COAL.

	Pratt seam.		Milner seam.		Woodward mines.
	No. 1.	No. 2.	No. 1.	No. 2.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	61. 600	64. 300	59. 69	55. 18	63. 458
Volatile matter	31. 480	32. 080	28. 24	36. 17	*a*31. 224
Ash	5. 416	2. 080	10. 92	7. 83	5. 318
Sulphur	. 918	. 470	. 64	1. 38	....
Moisture	1. 508	1. 070	. 50	1. 12	....
	100. 922	100. 000	99. 69	101. 68	100. 000

a Including moisture.

COKE.

	Pratt seam.	
	Lowest ash.	Highest ash.
	Per cent.	*Per cent.*
Fixed carbon	93. 01	83. 27
Volatile matter	. 16	. 93
Ash	6. 83	15. 06
Sulphur	....	. 74
	100. 00	100. 00

Analyses of the coals and cokes of the Cahaba field, Helena, Alabama.

	Coal.	Coke.(*a*)
	Per cent.	*Per cent.*
Fixed carbon	58. 69	84. 035
Volatile matter	35. 48	0. 066
Ash	3. 82	15. 216
Sulphur	. 90	. 445
Moisture	1. 74	. 683
	100. 63	100. 445

a This coke must have been made from screenings or from coal carelessly mined.

The following are the statistics of the manufacture of coke in Alabama from 1880 to 1884:

Statistics of the manufacture of coke in Alabama, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	4	4	5	6	8
Ovens built	316	416	536	767	*a* 976
Ovens building	100	120	....	122	242
Coal used, short tons	106, 283	184, 881	261, 839	359, 699	413, 184
Coke produced, short tons	60, 781	109, 033	152, 940	217, 531	244, 009
Total value coke at ovens	$183, 063	$326, 819	$425, 940	$598, 473	$609, 185
Value coke at ovens, per ton	$3. 01	$3. 00	$2. 79	$2. 75	$2. 50
Yield of coal in coke, per cent	57	59	58	60	60

a One establishment made coke on the ground.

Of the nine hundred and seventy-six ovens reported as built in 1884, all but eighty are beehive. These eighty are what are known as drag ovens, long ovens shaped like a muffle.

ARIZONA.

No coke has as yet been made in Arizona except a few hundred pounds to test the character of the coal. It is stated that veins of coking coal have been found in several localities in the Territory, but little reliable information can be obtained regarding them. Near Deer creek in Gila county, on the Indian reservation, veins of coking coal from 3 to 8 feet thick are reported to exist. These have been explored but little and have produced but little coal, and that only for domestic purposes.

COLORADO.

The only locality in the United States outside of the Appalachian basin in which coking has attained any importance as an industry is in Colorado. The production of coke in this State is exceeded only by that of Pennsylvania, West Virginia, Alabama, and Tennessee, that is, it ranked fifth in production in 1884, but only the seventh in 1880. The demand that has led to the development of the coke industry along the line of the Alleghanies has been chiefly in connection with the iron industries. To a large extent it has been iron and steel that have developed coking in Colorado, but in addition to this the demand for coke for smelting the ores of the precious metals and the high cost of this fuel when brought from the East have made the industry a profitable one, and have been largely instrumental in its development and extension.

El Moro or Trinidad district.—The oldest and most extensive coke works in the State is that of the Colorado Coal and Iron Company at El Moro in Las Animas county. Coking was begun here in 1879. There are now two hundred and fifty ovens built. Since 1879 the consumption of coal and production of coke has been as follows:

Production of coke in the El Moro district.

Years.	Coal sent to ovens.	Coke made.
	Short tons.	*Short tons.*
1879	....	10,786
1880	51,891	25,568
1881	95,040	47,166
1882	148,574	84,065
1883	164,181	109,016
1884	127,796	81,799

These ovens are 6 miles south of El Moro, near the boundary line of New Mexico, in what is called the Trinidad or El Moro coal field. The coal bed varies in thickness from 6 to 10 feet, showing in one instance, only, a local pinch to 3½ feet. Where the roof is bad 12 to 18 inches, and in some cases 2 feet, are left to keep it secure. About 7½ feet are available for mining. The bed is nearly horizontal, but has several seams of bony coal. The Lechner coal-cutting machine is used in the mine.

The coke made at El Moro is hard, light, and porous, but it is more friable than Connellsville coke; it makes more fine coke. It stands the burden in the iron furnace fairly well. Its amount of ash is probably from 18 to 20 per cent. The steel works report 18 per cent., the lead smelters from 20 to 22 per cent. of ash. The 18 per cent. is composed of 68.99 per cent. silica, 28 per cent. alumina, and 2.5 per cent. iron.

Formerly the coal at El Moro was washed by Stutz's system. This plan has been abandoned and the machinery has been made use of, wherever it could be done, for other purposes. The experience at El Moro was that too much coal was lost in washing to permit of its economical use. The yield, when washing the coal, was 53 per cent. against a present yield of, say, 60 to 65 per cent. Since the coke from washed coal commanded no extra price, and since the cost of crushing and washing the coal was from 12 to 15 cents a ton extra, washing the coal has been abandoned.

Analyses of the El Moro coals and cokes are as follows:

Analysis of El Moro, Colorado, coals and cokes.

	Coal.			Coke.	
	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	65.76	60.08	54.75	87.47	75.30
Volatile matter	29.66	34.48	35.79	....	5.20
Ash	4.32	3.78	8.12	10.68	19.50
Water	.26	1.66	1.34	[a]1.85	30
	100.00	100.00	100.00	100.00	100.30

[a] Including volatile matter.

At Starkville, in the same county, the Trinidad Coal and Coking Company began building ovens in 1881, and now has eighty-six ovens in operation. The coal at this place is from the same vein as at El Moro. At this point the workable coal is from 4 to 6 feet thick.

Crested Butte district.—The Colorado Coal and Iron Company also operates ovens at Crested Butte, in Gunnison county, 28 miles from Gunnison City. There are four distinct seams, the upper being 3½ and the lowest 10 feet thick, both carrying domestic and steam coals, and the two middle seams, 5 and 5½ feet thick, coking coals. The workings thus far have been confined principally to the upper coking seam, which rolls considerably and has shown some remarkable fluctuations in thickness. The bed lies at an angle of about 8°. The Crested Butte coke is not quite as dense as El Moro coke, and more friable. This makes the loss in transportation and handling greater, but the less dense coke is preferred by the lead smelters. The ash is less silicious than El Moro ash. The ash, as by the experience of the Harrison Reduction Works, in the Crested Butte coke varies from 10 to 14 per cent. It is composed of silica, 50.84 per cent.; iron, 20.16 per cent.; alumina, 13.80 per cent. Utah smelters are stated to express a preference for Crested Butte coke against Connellsville coke. The following are analyses of the Crested Butte coal and coke:

Analyses of Crested Butte coal and coke.

	Coal.		Coke.			
	No. 1.	No. 2.	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	72.60	72.30	92.03	90.71	92.44	87.11
Volatile matter	23.20	24.17	1.35	.42	0.41	0.56
Ash	3.10	3.09	6.62	8.87	7.15	12.30
Water	1.10	.44	....	....	....	....
Sulphur	....	....	....	.58	.37	.42
	100.00	100.00	100.00	100.58	100.37	100.39

From these three coke works already described, which have 386 ovens of the 409 in the State, practically all of the coke of Colorado is made. Much of the coke made in El Moro is consumed in the iron and steel works of the company making it, when they are in operation. What is not used in this way is sold to the lead smelters. All of the Trinidad and Crested Butte coke is consumed by smelters, the latter chiefly in Utah.

Other districts.—At Durango, in La Plata county, coking has been carried on since 1882, but in heaps or mounds until August 1, 1884, at which time eight ovens had been built. The coke is used in the lead-smelting works of the San Juan and New York Mining and Smelting Company, by whom it is made. The coal fields in the locality are reported to be quite extensive, and the coal similar to the El Moro. It yields about 50 per cent. in coke.

In Dolores county there are three coke works, with ten ovens, producing coke for the local smelters. The veins of coal are quite thin, the thickest being but 32 to 36 inches and the average 20 inches. Most of the coal mined is coked, but the production is quite small. The coke is high in ash, carrying from 18 to 25 per cent.

Some attempts have been made to coke the coal found at Como, Park county, but with little success, and the effort has been abandoned.

At Aspen, Pitkin county, the Jerome Park Coal Company has built five ovens during the past year. Nothing was learned concerning this enterprise but this fact.

The statistics of the manufacture of coke in this State for the years from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Colorado, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	2	5	7	8
Ovens built	200	267	344	352	409
Ovens building	50	0	0	0	24
Coal used, short tons	51, 891	97, 508	180, 549	224, 089	181, 968
Coke produced, short tons	25, 568	48, 587	102, 105	133, 997	115, 719
Total value coke at ovens	$145, 226	$267, 156	$476, 665	$584, 578	$409, 930
Value coke at ovens per ton	$5. 68	$5. 29	$4. 67	$4. 36	$3. 45
Yield of coal in coke, per cent	49	50	57	60	64

Some of the coke made in 1883 was in heaps on the ground. The increased yield is due in part to the giving up of coal washing.

GEORGIA.

The extreme eastern outcrop of the coal fields of the Appalachian basin in their southwesterly trend cuts the northwestern corner of the State of Georgia, furnishing a small patch of coking coal. From the coal of this field all the coke made in Georgia is produced. There is but one establishment, having 300 ovens in 1884, and producing in that year 79,000 tons of coke. Most of the coke produced is used at the Rising Fawn furnaces, in the same county as that in which the ovens are situated (Dade), and gives fairly good satisfaction. Some is also sent to Chattanooga and used at a furnace there. The coke has considerable ash, but it is thought to be more economical to flux this out in the furnace than to wash it out before coking. It is also believed that the unwashed coke is a better furnace fuel, being stronger and more vigorous than it would be were the ash removed by preliminary washing. The statistics of the manufacture of coke in this State for the years 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Georgia, 1880 to 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	1	1	1	1
Ovens built	140	180	220	264	300
Ovens building	40	40	44	36	0
Coal used, short tons	63, 402	68, 960	77, 670	111, 687	132, 113
Coke produced, short tons	38, 041	41, 376	46, 602	67, 012	79, 268
Total value coke at ovens	$81, 789	$88, 753	$100, 194	$147, 166	$169, 192
Value of coke at ovens per ton	$2. 15	$2. 15	$2. 15	$2. 20	$2. 13
Yield of coal in coke, per cent	60	60	60	60	60

ILLINOIS.

The coal fields of Illinois, according to Professor Worthen, underlie about 35,000 square miles of the surface of the State. In the measures of this enormous field sixteen different coal seams have been recognized, ranging from 1 to 9 feet in thickness, though the veins worked rarely exceed 6 feet, and where they are of this thickness there is usually a slate parting. Much of this coal would be classed as coking coal, but the chemical and physical character of that worked so far is such that as yet little or no coke has been made equal to the cokes of the Appalachian field.

In the many attempts to produce a merchantable coke from the coals of Illinois three difficulties have been encountered:

First, some of the best coking coals are quite impure, carrying a large percentage of both ash and sulphur. Even most thorough washing fails in many cases to remove these impurities. At one works 60 per cent. of the coal was washed away and there was still an excess of sulphur and ash. There are, of course, exceptions to this statement. The coal of the Big Muddy district is quite pure, and the coke made from it is comparatively low in sulphur and ash. This coal, however, is not as well adapted to coking as that of other portions of the State. It is a hard, semi-bituminous, free-burning fuel, but shows no tendency to run together or coke, even under extreme heat, unless first ground fine and wet.

A second difficulty with Illinois coal is that where it is sufficiently free from ash and sulphur it is too dry to coke well in beehive ovens, the form most commonly used. Much time and money have been expended in the search for the oven best adapted to the coking of these dry coals. At one works four varieties of ovens are reported. Notwithstanding these long-continued experiments, the question of ovens still seems in abeyance. The beehive, as a rule, has not made good coke. An oven known as the English drag, varying in dimensions at different works, the ovens at one establishment being 36 feet long, 7 wide, and 3½ high, with a capacity of 300 bushels, or 11 tons, has been used with good results, as has an oven known as the Thomas.

A third difficulty with Illinois coke is that generally it is not strong enough to bear the burden of furnace work without an admixture of Connellsville coke.

The only section in which this industry has assumed any importance is the Big Muddy region and its neighborhood, in the southwestern part of the State. This coal field or pocket covers an area of about 4,000 acres. The seam lies almost horizontal, with a slight drop to the north, and varies from 5 to 7 feet in thickness, with a thin slate parting.

Near this Big Muddy deposit, at Carterville, in Williamson county, is a small pocket of comparatively pure coal. The coal contains more bitumen than the Big Muddy, but more ash and sulphur. The vein is 9 feet thick, some 2 feet of which are left in the roof. The slack is transported to Harrison, Jackson county, where the company's coke works are located. As this slack is crushed and washed before coking, the ovens are located at Harrison to secure an abundant supply of water. At this place there are 108 ovens, 16 feet long, 6 feet wide, and 3½ feet high.

At Saint John's, Perry county, the Illinois Central Iron and Mining Company have eighteen ovens, making coke from the Paradise coal. The coke from this coal gives 90.44 per cent. of carbon and but 8.76 per cent. of ash and 0.80 per cent. of sulphur. These ovens have been in operation for several years, but the enterprise is still regarded as experimental.

In 1882 a block of fifty beehive ovens, with crushing and washing machinery, was built at Brussels, in Calhoun county. But little coke was made, the mine being closed by reason of the business depression. The coke made is reported to have been a good furnace fuel.

The Equality Coal and Coke Company, at Equality, Gallatin county, is making coke in a limited way, the coal being crushed and washed. The ovens are Belgian, 2 feet wide, 5 feet high, and 30 feet long. The charge is 5 tons. The coal is of an excellent quality, almost free from sulphur, and the coke is reported to be clean and strong.

At Brookside, in Madison county, there are six ovens for utilizing the nut coal and slack from the mines of the Brookside Coal and Coke Company. The coal is crushed and washed. The coke has been used by maltsters, blacksmiths, foundries, and pressed-brick works with good results.

Until quite recently the attempts to coke Streator coal were not at all successful. Within a short time the Luther & Tyler Coal and Coke Company has shown that a fair coke can be made from Streator screenings if thoroughly washed. This is the only merchantable coke that has been made either in the Streator or Wilmington coal fields. The company has but three ovens, making 75 tons a week. It will probably build more. The coke has about 80 per cent. carbon, 18 per cent. ash, and 2 per cent. sulphur.

There is also a block of twenty-four Belgian ovens opposite Saint Louis, in Saint Clair county. These were built to utilize the nut coal and slack from the Belleville coals, but the coke, though made from carefully washed coal, was too high in sulphur and ash to compete with that from other parts of the country.

The following are analyses of some Illinois coals and cokes:

Analyses of Illinois coals and cokes.

	Coals.		Cokes.					
	Big Muddy, Mount Carbon.		Big Muddy, Mount Carbon.		Carterville.		Saint John's.	Brookside.
Fixed carbon	59.13	57.06	87.32	88.18	86.79	80.14	90.44	87.10
Volatile matter	31.93	33.71	0.83	0.93	2.42	1.58	....	0.11
Ash	1.81	3.21	11.85	10.07	8.31	18.28	8.76	11.32
Sulphur	0.76	1.19	1.08	0.61	0.88	2.03	0.80	0.69
Water	6.37	6.02	....	....	2.48	....	....	0.49

The following are the statistics of the manufacture of coke in Illinois for the years from 1880 to 1884:

Statistics of the manufacture of coke in Illinois, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	6	6	7	7	9
Ovens built	176	176	304	316	325
Ovens building	0	0	0	0	0
Coal used, short tons	31, 240	35, 240	25, 270	31, 170	30, 168
Coke produced, short tons	12, 700	14, 800	11, 400	13, 400	13, 095
Total value coke at ovens	$41, 950	$45, 850	$29, 050	$28, 200	$25, 639
Value coke at ovens per ton	$3. 30	$3. 10	$2. 55	$2. 10	$1. 96
Yield of coal in coke, per cent.	41	42	45	43	43

Of the 325 ovens reported as built in 1884, 55 are beehive, 52 Belgian, 92 Thomas, and 126 English drag.

INDIANA.

No coke has been made in this State in the five years covered by this report, though there are two coke works in existence, and though it is claimed, and with good reason, that there is in Indiana a vast area of good coal adapted to making excellent coke. One reason why little coke has been made at any time in this State is that the block coal mined here is a very valuable fuel, and can be worked in blast furnaces in the raw state. Another reason probably is that as yet the industrial cokes made from the coals of Indiana have not been good fuels for iron making and melting, which is the chief use to which coke is put. The physical constitution of the coke was bad, it being weak and cellular, and, in addition to this, the cokes are high in ash.

Probably the most thorough and careful attempt yet made to coke Indiana coal was that of the North Chicago Rolling Mill Company. The coal used was screenings of Coal Creek coal from Fountain county. These screenings contained from 15 to 20 per cent. of ash, which was reduced by washing so that the coke contained only from 10 to 12 per cent. The sulphur, however, was from 0.75 to 1.25 per cent. Belgian ovens with Enders's modifications were used. The coke, besides being high in sulphur, was spongy and soft, and would not carry a burden in the furnace; but when mixed in the proportion of from 10 to 15 per cent. with Connellsville coke fairly good results were obtained. Mr. O. W. Potter, president of the company making the experiments, writes: "We are not sure but further experiments in using lump and nut coal and crushing to remove the slate may give us better results than we have had up to this time."

As already stated, there are nominally two coke works in Indiana. At these two coke works there were forty-five ovens in 1880. At one works, that of the Central Iron and Steel Company, situated at Brazil, eight of the ovens have been abandoned, and but twelve are in a condition to resume work should it ever be deemed advisable. At the other works, in Fountain county, though the ovens are still standing, all operations have been abandoned. As the ovens are in existence, however, they are reported, giving a total at the present time of thirty-seven ovens in the State.

INDIAN TERRITORY.

There is but one coke works in Indian Territory, that of the Osage Coal and Mining Company, located at McAlister, Tobocksey county (Choctaw Nation). This company has twenty beehive ovens, in which the refuse slack produced in the mining operations is coked. The following are analyses of the coal and coke:

Analyses of McAlister, Indian Territory, coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Moisture	2. 10	. 325
Volatile matter	29. 71	1. 560
Fixed carbon	62. 67	88. 140
Ash	5. 52	9. 975
	100. 00	100. 000

The coke is free from sulphur and phosphorus and has an excellent reputation among the foundries, blacksmith shops, and breweries of Kansas and Nebraska and western Missouri and Iowa.

The statistics of the manufacture of coke in this Territory for the years 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Indian Territory, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	1	1	1	1
Ovens built	20	20	20	20	20
Ovens building	0	0	0	0	0
Coal used, short tons	2, 494	2, 852	3, 266	4, 150	3, 084
Coke produced, short tons	1, 546	1, 768	2, 025	2, 573	1, 912
Total value coke at ovens	$4, 638	$5, 304	$6, 075	$7, 719	$5, 736
Value coke at ovens per ton	$3	$3	$3	$3	$3
Yield of coal in coke, per cent	62	62	62	62	62

In the returns received no statement as to coal used was included, slack only being used. A yield of 62 per cent. has been assumed.

IOWA.

Several years since some coke ovens were built in the Ottumwa district for the purpose of utilizing the slack from a number of the coal banks. The enterprise was not successful. The ovens were abandoned and have been in ruins for some years, and no coke is at present made in the State.

KANSAS.

But little coke is made in Kansas, and what is produced is chiefly to utilize the fine coal and slack. The most valuable of the workable veins of coal yet discovered in this State are in the southeastern part, in Cherokee and Crawford counties, and are a spur or portion of the southwestern Missouri coal field. All the coke works of the State draw their supplies of coal from these veins. Seventeen of the ovens and two of the four works in the State at the close of 1884 were in Crawford county, the others in Cherokee. The coke is known locally as "Cherokee coke." In some instances the mine proprietors coke their own slack; in others they furnish it to oven proprietors, who coke it for their own use. The coke works are small, the largest having but twelve ovens, two of the others but three each, and the fourth five. The coke is reported to be only fair, containing considerable ash and sulphur. The coal at a prominent mine in Crawford county is from 3 feet 2 inches to 3 feet 4 inches, and sometimes 4 feet, and is divided into four benches by three partings. These partings carry considerable iron pyrites and gypsum. Frequent "horsebacks" are also encountered. The following is an analysis of the coal:

	Per cent.
Hydroscopic moisture	1.29
Volatile combustible substances	35.72
Fixed carbon	53.97
Ash	9.02
	100.00

It is stated that the coal contains 5 per cent. of sulphur. The coke is hard, with a metallic luster. The ash is a light reddish brown. It is used for domestic purposes and in smelting, all but one bank of ovens being operated by zinc smelters, who burn coke only for their own furnaces. The coke finds its chief market among the smelters in the neighborhood of the ovens and for domestic purposes at Kansas City. The statistics of the manufacture of coke from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Kansas in 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	2	3	3	4	4
Ovens built	6	15	20	23	23
Ovens building	0	0	0	0	0
Coal used, short tons	4,800	8,800	9,200	13,400	11,500
Coke produced, short tons	3,070	5,670	6,080	8,430	7,190
Total value coke at ovens	$6,000	$10,200	$11,460	$16,560	$14,580
Value coke at ovens per ton	$1.95	$1.80	$1.70	$1.96	$2.02
Yield of coal in coke, per cent	64	64.4	65	62.9	62.5

In 1880 and 1881 some of the coke reported as made was produced at one establishment in pits.

KENTUCKY.

But little of the coke made in Kentucky is from the coals of the State. Practically the entire output was burned in the ovens built on the Ohio opposite Cincinnati, in which are utilized the screenings from the coal yards established for distributing the upper Ohio coals.

There are in this State two coal fields: first, the eastern, of some 8,700 square miles in extent, a western extension of the coal fields of West Virginia; and second, the western, covering some 4,000 square miles, the southern extension of the Indiana deposits. Much of the coal field of the eastern deposit is so situated relative to transportation that a coking coal would have at the present time but a limited market. In addition to this, little coal has been found that makes a good industrial coke. Prof. John R. Proctor, of the State Geological Survey, some time since announced the existence of a coal in southeastern Kentucky remarkable for thickness, purity, and its high percentage of carbon, which he has named the "Elkhorn coking coal." This coal has been identified and traced over a large area on the headwaters of the Big Sandy, Licking, Kentucky, and Cumberland rivers, where it was found from 8 to 9 feet thick. This coal was coked by officers of the Geological Survey by building ricks on the ground, and was also sent to coke ovens at Cincinnati and in Connellsville, Pennsylvania. Analyses of the cokes by Dr. Peter give the following results (No. 1 was made in an oven at Cincinnati, No. 2 at Connellsville):

Analyses of cokes made from southeastern Kentucky coals.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	.20	1.20
Fixed carbon	93.20	94.14
Ash	6.60	4.66
	100.00	100.00
Sulphur	0.734	1.484

The cokes are firm, bright, and, as will be seen, quite pure, but, so far as has been learned, no use has been made of the coal for coking on a commercial scale.

Some years since attempts were made to utilize the coals of Carter county for the manufacture of coke for blast-furnace purposes, but with little success. The coke was dense, weak, and quite high in sulphur, though bright looking. The following is an analysis:

	Per cent.
Hydroscopic moisture	2.46
Volatile combustible matter	1.84
Fixed carbon	87.34
Ash	8.36
	100.00
Sulphur	2.026

No coke has been made in this district on a commercial scale.

Some careful and thorough tests have been made as to the adaptability of the coals of the western field to make an industrial coke. The results have not been satisfactory, and the only coke made in this section in the four years covered by this report has been in very small amounts for domestic use. Attempts were made a number of years ago to run some of the charcoal furnaces of this district on coke. An analysis of a sample of coke that had been weathered sixteen years, made at the old Airdrie furnace, showed but 5.40 per cent. of ash, with but 0.64 per cent. of sulphur and with 82.90 per cent. of carbon.

The most exhaustive experiments with the coals of this district have been made at the instance of the Saint Bernard Coal Company, of Earlington, Hopkins county, the most extensive miner of coal in the State. The tests and analyses were made at the Cambria Iron Works, Johnstown, Pennsylvania, by Mr. John Fulton and Mr. T. T. Morrell. The table exhibits the physical and chemical properties of the Saint Bernard coke as compared with Connellsville:

Comparison of Connellsville and Saint Bernard cokes.

	Locality.	
	Standard coke, Connellsville.(a)	Saint Bernard, Kentucky.(b)
Grams in 1 cubic inch:		
Dry	12.46	12.87
Wet	20.25	20.92.
Pounds in 1 cubic foot:		
Dry	47.47	49.03
Wet	77.15	79.70
Percentage:		
Dry	61.53	63.59
Wet	38.47	36.41
Compressing strength per cubic inch, one-fourth ultimate strength	284	328
Height of furnace charge supported without crushing	114	131
Order in cellular space	1	1
Hardness	3.5	3.2
Specific gravity	1.500	1.400
Chemical analysis:		
Fixed carbon	87.46	86.94
Moisture	0.49	....
Ash	11.32	12.10
Sulphur	.69	1.96
Phosphorus	.029	.012
Volatile matter	.011	....

[a] Authority, Prof. A. S. McCreath.

[b] Authority, T. T. Morrell.

Regarding these tests Mr. Fulton writes: "From this table the very close resemblance of the physical structure of the Saint Bernard coke to that of Connellsville will be observed. It is so nearly equal to it in cellular space and hardness that no distinction should be drawn. Its burden-bearing property slightly exceeds the Connellsville." This coke was made from washed slack. The sulphur is undoubtedly lower than would be found in ordinary practice. It is doubtful if coke can be made regularly from these coals with less than 2 to 2.5 per cent. of sulphur.

All the coke made in the western district was made from the Saint Bernard coal for domestic consumption. The yield of the coal in the oven is from 49 to 55 per cent.

The following are the statistics of the manufacture of coke in Kentucky in the years from 1880 to 1884. The Cincinnati district includes those ovens using screenings from the coal yards on the Ohio at and near Cincinnati. One works, with six ovens, was not in operation in 1884. The western district includes the ovens in the western coal field. One of these works is the Saint Bernard, already spoken of; the other is at Mercer station, in Muhlenberg county. In these latter ovens no coke was made during the years covered by the report.

Statistics of the total manufacture of coke in Kentucky, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	5	5	5	5	5
Ovens built	45	45	45	45	45
Ovens building	0	0	0	0	0
Coal used, short tons	7,206	7,406	6,906	8,437	3,451
Coal produced, short tons	4,250	4,370	4,070	5,025	2,223
Total value of coke at ovens	$12,250	$12,630	$11,530	$14,425	$8,760
Value coke at ovens per ton	$2.88	$2.89	$2.83	$2.87	$3.94
Yield of coal in coke, per cent	60	60	59	60	64

Statistics of the manufacture of coke in the Cincinnati district, Kentucky, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	3	3	3	3	4
Ovens built	36	36	36	36	36
Ovens building	0	0	0	0	0
Coal used, short tons	7,206	7,406	6,906	8,272	3,316
Coke produced, short tons	4,250	4,370	4,070	4,950	2,158
Total value of coke at ovens	$12,250	$12,630	$11,530	$14,275	$8,630
Value coke at ovens per ton	$2.88	$2.87	$2.83	$2.88	$4
Yield of coal in coke, per cent	60	60	59	59	60

Statistics of the manufacture of coke in the western district, Kentucky, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	2	2	2	2	2
Ovens built	9	9	9	9	9
Ovens building	0	0	0	0	0
Coal used, short tons	0	0	0	165	135
Coke produced, short tons	0	0	0	75	65
Total value of coke at ovens	0	0	0	$150	$130
Value coke at ovens per ton	0	0	0	$2	$2
Yield of coal in coke, per cent	0	0	0	45	48

MONTANA.

All the coke yet produced in Montana has been experimental, to test the coking qualities of the coal and the value of the coke as a fuel. These experiments have been chiefly, if not entirely, with the coals of what is known as the "Bozeman field." Mr. George T. Wickes, M. E., formerly manager of the Low Moor iron works of Virginia, and fully competent to give an opinion, has during the past two years built three ovens in different places in the neighborhood of Bozeman, and tested the coal. He reports that the coke made was firm, bright, and porous, with a good structure and a clear metallic ring. It required from 2 to 2¼ tons of coal to make a ton of coke. That burned forty-eight hours seemed the best. The following is an analysis of the coke:

Analysis of Bozeman, Montana coke.

	Per cent.
Water	.66
Fixed carbon	77.00
Ash	22.75
	100.41

The coal was not washed, and hence the high ash. Mr. Wickes thinks that this can be removed to a large extent by washing.

From other sources it is learned that the Bozeman field is about 5 miles square. The veins are from 3½ to 4 feet thick, with a dip of from 35° to 80°, averaging 45°; so that the width of the available field is not over 2,000 feet. The coal is stated to contain from 34½ to 41½ per cent. volatile matter, from 43½ to 50 per cent. of fixed carbon, and from 8 to 12 per cent. of ash.

Experiments in coking this coal have been undertaken by the Northern Pacific Railroad Company, the Union Pacific Railroad Company, and Messrs. Quealy & Hoffman. These latter gentlemen report that they have demonstrated that this coal is well adapted for making coke. They have erected two beehive ovens, 11½ feet by 5½, and have the material on the ground ready for twelve more ovens of the same pattern. Four carloads of the coke made have been supplied to Montana smelters, and some used for domestic purposes, in each case with good results.

There are other fields of coking coal reported, but no definite information regarding them has been obtained. The statistics of the manufacture of coke in Montana from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Montana, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	0	0	0	1	3
Ovens built	0	0	0	2	5
Ovens building	0	0	0	0	12
Coal used, short tons	0	0	0	0	165
Coke produced, short tons	0	0	0	0	75
Total value coke at ovens	0	0	0	0	$900
Value of coke at ovens per ton	0	0	0	0	$12
Yield of coal in coke, per cent	0	0	0	0	46

The above figures as to production and prices are estimates.

NEW MEXICO.

The only coke ovens in New Mexico at the close of 1884 were those of the San Pedro Coal and Coke Company, at San Antonio, on the Rio Grande. These ovens are on the line of the Atchison, Topeka and Santa Fé railroad, and, with those at Starkville, Colorado, are in their management closely identified with that railroad.

The San Pedro coal is a good coking coal, with some 5 per cent. of ash, yielding 56¼ per cent. of coke. The vein is from 5½ to 6 feet thick. The field has been greatly disturbed; faults are common and the coal comes out much broken. The vein lies at an angle of from 10° to 15°. The erection of ovens was begun by this company in 1882, but no coke was made until 1883. The results obtained in coking this coal were so satisfactory that the twelve ovens completed in 1883 were increased to seventy in 1884, and the production from 3,905 tons in 1883 to 18,282 tons in 1884. The coke is used by the Billings smelter at Socorro, and shipped to other points in New Mexico and to Arizona and Mexico. The value of the coke produced at this works, as given in the accompanying table, is an estimate.

Some coke has also been produced in the Cerrillos mining district, in Santa Fé county. In 1883, prior to the building of the San Pedro ovens, ten stone pits, with a capacity of 10 tons of coke each, were built at Waldo Banks, and about 1,000 tons of coke made in that year from some 1,500 tons of coal. This coke was tested at the Billings smelter at Socorro, New Mexico, the Grant smelter at Denver, the Arizona Copper Company, and others, "who all pronounced it the equal of Connellsville coke, and by far the best coke made in the West." In 1883 and 1884 no coke was made, owing, it is stated, to difficulties about railroad freight. Since the beginning of 1885 burning in the pits has been resumed, and the immediate erection of ovens is contemplated. It is claimed that the Cerrillos coal is an exceedingly pure coal. The veins are from 2 to 5 feet thick, free from slate or bone, with a drop of about 12°.

The following are the statistics of the manufacture of coke in New Mexico from 1880 to 1884:

Statistics of the manufacture of coke in New Mexico, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	0	0	2	2	2
Ovens built (*a*)	0	0	0	12	70
Ovens building	0	0	12	28	0
Coal used, short tons	0	0	1,500	6,941	29,990
Coke produced, short tons	0	0	1,000	3,905	18,282
Total value of coke at ovens	0	0	$6,000	$21,478	$91,410
Value coke at ovens per ton	0	0	$6	$5.50	$5
Yield of coal in coke, per cent	0	0	66⅔	57¼	57¼

a At one works there are ten stone pits, with an average capacity of 10 tons each.

OHIO.

The cokes produced in Ohio from the coals of the State are made chiefly in the vicinity of Leetonia, Columbiana county, and Steubenville, Jefferson county. Some little is made in the Hocking valley, at Bridgeport, Belmont county, and in other localities, but the total amount is very small. Its manufacture has been abandoned at Port Washington, at Canal Dover, and in other sections. A very little is burned near Zanesville for local domestic consumption, and there are also in Cincinnati and vicinity several blocks of ovens, in which in the aggregate considerable coke is made from the screenings and dust from the coal boats and coal yards.

While most of the coal of this State is classed as coking, so far but little has been found as well adapted to the manufacture of coke as some of the coals of Pennsylvania, West Virginia, and Alabama, though the coal fields are part of the great Appalachian basin, and the seams the same in some instances as those from which coke is made in Pennsylvania and West Virginia. The coals of these seams both east and west from Connellsville appear to lose to some extent their value as coking coals. Some of the cokes of Ohio are lower in ash than that made in Pennsylvania, but, as has been stated elsewhere, relative purity is not always an indication of the economic value of a coke. The Ohio cokes are usually soft, brittle, high in sulphur, and in many cases in ash also, though this is not always true. The Steubenville coke is low in ash, but is a very weak coke, breaking easily and not bearing transportation, a large part of it becoming dust even in transporting it but a few hundred yards from the ovens to the blast furnace. The Washingtonville coke, made at Leetonia, the only other Ohio coke used in blast furnaces, is also a pure coke, not as compact as Connellsville, will not stand transporting as well, but is regarded as better than Connellsville in smelting the native ores, and is equal to it in carrying burden.

Washingtonville coke.—The coke made in the vicinity of Leetonia, Columbiana county, is made from coal in part from Columbiana county and in part from Mahoning county, the county lines in some cases running through the mines from which the coal is procured. There are three coke works in this district, one of which, with ten ovens, made no coke during the years covered by this report, and a second, with fifty ovens, is now idle and has been for two years. During 1880–'82, one hundred and ninety-four ovens were in operation, and in 1883–'84 but one hundred and forty-four. The coal from which this coke is made corresponds to the Lower Kittanning of the Pennsylvania survey. It is a valuable deposit, but it is the thinnest coal worked in a large way in Ohio. The greatest thickness at the Cherry Valley mines is 3 feet, the average 30 inches. The upper 4 to 6 inches is hard and slaty, and is not coked, only the 2 feet at the bottom being used in the ovens. Sometimes the run of the mine is coked, but frequently only the slack from a 2-inch screen, the lump in such cases being sold or used at the furnace or rolling mill of the company. The following are analyses of this coal and coke, both from the Cherry Valley mines, No. 1 from Leetonia and No. 2 from Washingtonville:

Analyses of Washingtonville (Leetonia), Ohio, coal and coke.

COAL.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	3. 60	4. 37
Volatile matter	37. 86	35. 50
Fixed carbon	56. 14	57. 91
Ash	2. 40	2. 22
	100. 00	100. 00
Sulphur in ash	82	69

COKE.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Ash	8. 47	5. 86
Sulphur	1. 08	61

Complete analyses of the coke are as follows:

Analyses of Washingtonville (Leetonia), Ohio, coke.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Carbon	93. 75	95. 50
Ash	5. 38	3. 30
Sulphur in ash	. 87	1. 20
	100. 00	100. 00
Silica	....	3. 02

The following are the statistics of the manufacture of coke in this district from 1880 to 1884:

Statistics of the manufacture of coke in the Washingtonville district, Ohio, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	3	3	3	3	3
Ovens built	204	204	204	204	204
Ovens building	0	0	0	0	0
Coal used, short tons	76, 321	66, 972	67, 516	57, 785	53, 363
Coal produced, short tons	43, 433	39, 718	36, 646	31, 304	29, 933
Total value of coke at ovens	$128, 608	$119, 383	$110, 617	$87, 651	$68, 806
Value coke at ovens per ton	$2. 96	$3. 01	$3. 01	$2. 80	$2. 90
Yield of coal in coke, per cent	57	59	54	54	57

Steubenville coke.—This coal field, in which are included the ovens in Jefferson and Belmont counties, is one of the most important as it is one of the oldest worked and best known in Ohio. The coke made in Steubenville is from what is known locally as the Steubenville shaft coal, corresponding to the Lower Freeport of Pennsylvania. It ranges from 3 to 5 feet in thickness, the average being perhaps 4 feet. The following are analyses of the shaft coal and coke made from it in the ovens of the Steubenville Furnace and Iron Company:

Analyses of Steubenville shaft coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Water	1.40	....
Volatile combustible matter	30.90	....
Fixed carbon	65.90	90.63
Ash	1.80	8.38
	100.00	
Sulphur	.98	.27
Hydrogen	....	.72
		100.00

The coke, as already stated, is so weak and friable that it has been found more economical to use a portion of Connellsville with it in blast-furnace work. The following are the statistics of the manufacture of coke in this district from 1880 to 1884:

Statistics of the manufacture of coke in the Steubenville district, Ohio, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	7	7	8	9	10
Ovens built	360	385	391	401	451
Ovens building	25	0	0	0	0
Coal used, short tons	77,486	111,561	92,199	57,961	21,217
Coke produced, short tons	45,835	65,752	54,161	35,313	13,356
Total value coke at ovens	$83,789	$122,953	$106,971	$70,631	$25,691
Value coke at ovens per ton	$1.83	$1.87	$1.98	$2	$1.92
Yield of coal in coke, per cent	59	59	59	61	63

Hocking Valley coke.—The only coke made in the Hocking valley is at Happy Hollow, from the Upper Freeport coal. The ovens at this place were built as an experiment to test the coking qualities of the slack, which accumulates in large quantities, and not only had no value but its removal entailed considerable expense. To avoid this expense and to give some value to the slack, it is coked. The coke made was fairly firm, but too high in sulphur for smelting purposes. Experiments in washing out the sulphur have been quite successful, and separating machinery is now being erected, when it is believed that there will be a much better demand for the improved product. It is not probable that the washed coke will have much value as a furnace fuel. This is of but little moment, however, as much of the coal in the valley is adapted to use in the furnace raw.

The following are the statistics of the manufacture of coke in this district from 1880 to 1884:

Statistics of the manufacture of coke in the Hocking valley, Ohio, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	1	1	1	1
Ovens built	20	20	20	20	20
Ovens building	0	0	0	0	0
Coal used, short tons	2,505	1,905	2,175	2,778	1,450
Coke produced, short tons	1,002	762	870	1,111	580
Total value of coke at ovens	$1,253	$953	$1,088	$1,388	$725
Value coke at ovens per ton	$1.25	$1.25	$1.25	$1.25	$1.25
Yield of coal in coke, per cent	40	40	40	40	40

Cincinnati coke.—All the coke made in Cincinnati is from the screenings and small coal of the coal yards and boats. Most of the coal coming to Cincinnati is brought by the Ohio river in boats and barges, from which it is elevated into the numerous coal yards of the city. Large amounts of fine and small coal result from the weathering and hauling, and this is coked. Though made in Ohio, therefore, but little of the coal used is from this State. The following are the statistics of the manufacture of coke in this district from 1880 to 1884:

Statistics of the manufacture of coke in the Cincinnati district, Ohio, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	4	4	4	5	5
Ovens built	32	32	32	57	57
Ovens building	0	0	0	0	0
Coal used, short tons	16,141	20,607	19,687	33,978	32,134
Coke produced, short tons	10,326	13,237	12,545	20,106	18,840
Total value coke at ovens	$42,255	$54,439	$47,437	$65,990	$61,072
Value of coke at ovens per ton	$4.09	$4.11	$3.78	$3.28	$3.24
Yield of coal in coke, per cent	64	64	64	59	59

Other Ohio cokes.—Rush Run coke is made from the same coal as the Steubenville shaft, and is very similar in its character.

Some little coke was formerly made at Hammondsville, Jefferson county, from what is known as the Strip vein (Middle Kittanning). For some years this vein was worked for coking, the coke being hard and firm, outranking all other Ohio cokes in this respect, but was high in ash and sulphur, an analysis of coke, probably of an inferior character, showing 19.51 per cent. of ash and 3.36 per cent. of sulphur.

Efforts have been made to utilize the slack of the coal of the Big vein (Upper Freeport) at Salineville. Two grades of coke have been made, a soft coke for domestic purposes, with 14.07 per cent. of ash and 2.73 per cent. of sulphur, and a harder grade, with 17.47 per cent. of ash and 3.66 per cent. of sulphur.

At Bridgeport the La Belle Glass Company have made some coke for use in their glass works. They have but two ovens.

Some coke for domestic use, but in very small quantities, is made near Zanesville from the Upper Zanesville (Middle Kittanning) coal. It is quite high in sulphur and ash. In 1872 ovens were erected and some coke was made and used in the blast furnace at Zanesville, with fair results. The enterprise was abandoned. At present there are four ovens in this district, but no coke has been made for several years.

Statistics for Ohio.—The following are the statistics for the manufacture of coke in Ohio for the years from 1880 to 1884:

Statistics of the manufacture of coke in Ohio, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	15	15	16	18	19
Ovens built	616	641	647	682	732
Ovens building	25	0	0	0	0
Coal used, short tons	172, 453	201, 045	181, 577	152, 502	108, 164
Coke produced, short tons	100, 596	119, 469	103, 722	87, 834	62, 709
Total value coke at ovens	$255, 905	$297, 728	$266, 113	$225, 660	$156, 294
Value coke at ovens per ton	$2. 54	$2. 49	$2. 57	$2. 57	$2. 49
Yield of coal in coke, per cent	58	59	57	58	58

PENNSYLVANIA.

For convenience of reference the coke ovens of Pennsylvania have been divided into ten districts, as follows:

1. Connellsville.
2. Irwin-Latrobe (Pennsylvania Railroad).
3. Alleghany Mountain and Somerset.
4. Show Shoe.
5. Broad Top.
6. Pittsburgh.
7. Beaver.
8. Alleghany Valley.
9. Low Grade or Bennett's Branch.
10. Blossburg.

The bituminous coal regions of western Pennsylvania were divided by Professor Rogers, in his Report of the First Geological Survey of Pennsylvania, into six principal basins, numbered from the Alleghany mountains on the east to the Ohio river on the west. Five great anticlinal waves of remarkable persistence and regularity separate these basins, one of these, the anticlinal that bounds the Connellsville basin on the west, running from the Virginia State line to Elk county, a distance of 100 miles, in an absolutely straight line. Some of these basins coincide with the physical division of the surface. The first basin, for example, lies between Laurel Hill and the Alleghany mountains, and the second between Chestnut ridge and Laurel Hill. Other basins, however, are only geological, and have no strongly marked corresponding surface depressions.

In all of these basins coke was made during the period covered by this report. The bulk of the product, however, was from the Alleghany Mountain and the Connellsville regions. Most of the coke was made from the coal of the great Pittsburgh seam, which is, on the whole, the most extensive and important coal bed in the Appalachian basin. It is the main seam worked at Pittsburgh, on the Monongahela and Youghiogheny rivers, at Connellsville, Wheeling, and many other places, and is estimated to underlie, in the States of Pennsylvania, Ohio, and West Virginia, 14,000 square miles. In southwestern Pennsylvania Professor Lesley estimates that this bed, after all the erosion it has undergone, is found over an area of somewhat less than 3,000 square miles, so situated that every square yard of it can be reached. This bed does not everywhere show the same thickness as in western Pennsylvania, where it is generally about 8 feet, gradually increasing eastwardly to the Cumberland (Maryland) region, where it is 14 feet; nor does it always make as good coke as that of the Connellsville region, where it is seen at its best.

Connellsville district.—The Connellsville region or basin, the great coke-producing center of the country, is situated in the southwestern part of Pennsylvania, in the counties of Westmoreland and Fayette, some 50 or 60 miles from Pittsburgh. It is a slender prong separated from the Upper Coal Measures, and may be regarded as extending from near Latrobe, on the Pennsylvania railroad, in a southwesterly direction to the Virginia line, forming a basin some 3 miles wide and 50 long, almost without a fault, the beds yielding from 8 to 10 feet of workable coal. The same trough that contains the Connellsville coal extends northwesterly from Latrobe through the remainder of Westmoreland county and through Indiana and Clearfield counties, but the Connellsville region is regarded as extending no farther north than the vicinity of Latrobe. The coal in the northern part is inferior as a coking material to that in the southern part, though both physically and chemically the coal of this basin on the Conemaugh seems the same as that on the Youghiogheny. The latter, however, produces the typically Connellsville coke, compact, silvery, and lustrous; while the coke from the coal on the Conemaugh, or in any locality north from the Pennsylvania railroad, is tender, dull, and soon loses what little luster it has. Even in some portions of what is known as the Connellsville region proper the coal and coke are not of equal value. Coal at Coketon, in the northern part of the immediate Connellsville basin, just south of the Pennsylvania railroad, produced wretched coke when coked as it came from the mines, but when washed it produced a coke regarded as fully equal to the Connellsville. The coal at Latrobe and at Loyalhanna, in the same locality, must also be washed before coking to produce the best results.

The coal bed from which the so-called Connellsville coke is made is the Pittsburgh bed of Professor Roger's Report of the First Geological

Survey of Pennsylvania, of 1842, and is described in the second volume of the final report, of 1858. The continuation of the Pittsburgh area of this bed with the Connellsville area is broken off by the Youghiogheny river, the bed taking an upward course and descending again, the intermediate portion being swept away. This has led to a popular belief that the bed at Connellsville is different from that at Pittsburgh, but careful surveys have established their identity. It is a fact, however, that at Pittsburgh this bed is not in its best condition, while at Connellsville it is at its greatest thickness and is of the finest quality. It is also true that the coke made from the bed at Pittsburgh is not as good as that made at Connellsville. In the Connellsville basin the coal ranges from 8 to 11 feet in thickness, with one small slate parting, the "bearing-in slate," 18 inches above the floor. The roof is only passable; the rooms can only be run 12 feet wide, and the pillars will average 10 feet, a large amount of which is lost in drawing. The floor is even and quiet; the coal is of a remarkably good and uniform character and is soft and easily mined. On wagers, 23 wagons (57,684 pounds) have been dug and loaded inside of ten hours by a man and a boy. The greater portion of the work is to shovel the coal into wagons, the digging or mining being the easiest part. Very little outside labor is required, and the average output per man per day is from 8 to 10 wagons, the cost of digging being about 25 cents per ton. It is this ease of mining which, next to its chemical and physical characteristics, gives the Connellsville coke so much value as a material for coke, and has enabled the latter to compete in such distant markets with other cokes and fuels. Mr. Fulton has pointed out that this ease of mining is also a distinguishing peculiarity in the Connellsville basin. East or west from this narrow strip the cost of mining increases; westward the coal hardens, eastward the beds become thinner.

The coal is bituminous, with generally a dull, resinous luster, alternating with seams of bright, shining, crystalline coal, coated with a yellowish silt. It contains numerous particles of slate and some crystals of pyrites; is compact, with a tendency to break up into cubes; is a very tender coal, and is ill-adapted for shipping. Such a coal from the mines of the H. C. Frick Coke Company, at Broad Ford, is taken by the Pennsylvania Geological Survey as the typical coal of the Connellsville basin. Its analysis, as determined by Mr. McCreath, chemist of the survey, is:

	Per cent.
Water	1.260
Volatile matter	30.107
Fixed carbon	59.616
Sulphur	.784
Ash	8.233
	100.000

Color of ash, reddish gray; coke, per cent., 68.633; sulphur left in coke, 0.512.

	Per cent.
Percentage of sulphur in coke	.746
Percentage of ash in coke	11.995
Percentage of carbon in coke	87.250
	99.991

The coke from this region is of silvery luster, cellular, with a metallic ring, tenacious, comparatively free from impurities, and is capable of bearing a heavy burden in the furnace. Its porosity and ability to "stand up" in the furnace are what have given it such a reputation as a blast-furnace fuel, and have created such a demand for it for mixing with anthracite and bituminous coal in the East and West, especially where an open iron, such as is used in the Bessemer process, is needed.

In coking the Connellsville coal the beehive oven is in universal use in the Connellsville region, these ovens varying at the different works from 11 to 12 feet in diameter and from 5 to 6 feet in height. The working is very simple. The coal is dumped through an opening in the crown of the furnace and spread evenly on the floor to the average depth of 2 feet for 48-hour coke and 2½ feet for 72-hour. The front opening, through which the coke is discharged, is at first nearly closed with brick luted with loam. The heat of the oven from the previous coking fires the charge, and as the coking progresses the air is more and more shut off by luting the openings and finally closing the roof openings. The average charge is 100 bushels (76 pounds each) of coal, and the yield in coke is from 63 per cent. to 65 per cent. The average time of coking is 48 hours, with 72 hours for that burned over Sunday; 24-hour coke is sometimes made. The 72-hour coke is a firmer coke than either of the others, but it is questionable whether it is a better furnace coke. When the coke is thoroughly burned, the door is removed, and the coke is cooled by water thrown in from a hose, and is then drawn.

We have given above an analysis of what is regarded as the typical coal from this region, from the mines of the H. C. Frick Coke Company at Broad Ford, and also an analysis of a coke made in the laboratory. A sample of the coke from these mines made in the ovens of the firm, analyzed by Mr. McCreath, gave the following results. The coke is exceedingly coherent and compact, with a silvery luster, and contains some slate.

Analysis of Broad Ford (Connellsville) coke.

	Per cent.
Water	.030
Volatile matter	.460
Fixed carbon	89.576
Sulphur	.821
Ash	9.113
	100.000

Mr. Platt, of the Pennsylvania Geological Survey, in his report on coke, takes this as the typical coke, "as being thoroughly burned and as well made as can be produced in the Connellsville basin." Probably the most thorough analyses of the coke from this region were made by Mr. J. Blodget Britton, of Philadelphia. The result reached is given below. It is the average of a large number of analyses of all sorts of Connellsville coke, and cannot, therefore, be regarded as a fair analysis of good coke.

Average analysis of Connellsville coke (Britton).

	Per cent.
Moisture	.490
Ash	11.332
Sulphur	.693
Phosphoric acid	.029
Carbon, by difference	87.456
	100.000

Mr. E. C. Pechin gives a typical verified analysis of Connellsville coke as follows:

Average analysis of Connellsville coke (Pechin).

	Per cent.
Volatile matter	1.296
Carbon, hydrogen, and nitrogen	89.147
Ash	9.523
Water	.032
Sulphur	.084
	100.082
Ash ignited:	
Silica	5.413
Alumina	3.262
Sesquioxide of iron	.479
Lime	.243
Magnesia	.007
Phosphoric acid	.912
Potash and soda	Traces.
	100.316

In commenting on this analysis, Mr. Pechin, who has had considerable experience with Connellsville coke, says: "A large number of analyses of Connellsville coke have been made showing less carbon and more sulphur. As regards carbon, I have had a number of analyses made at different times out of different lots, showing somewhat more carbon than the above." It will be noted that Mr. Pechin's analysis corresponds very closely with that given above from the Pennsylvania Geological Survey, and from the best evidence I have been able to obtain I regard these two as fairly representing the average of good Connellsville coke. At the Edgar Thomson steel works, near Pittsburgh, a large amount of coke is used from the works of the H. C. Frick Coke Company, and frequent analyses for ash are made. The average of a large number of these analyses, covering the deliveries of 150,000 tons, extending from May 25 to November 18, 1882, gave 9.75 per cent. of ash, the range being from 9.11 to 10.91 per cent.; 9.75 may be regarded, therefore, as the average ash in good Connellsville coke.

The following are the statistics of the manufacture of coke in the Connellsville region proper from 1880 to 1884:

Statistics of the manufacture of coke in the Connellsville region, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	67	70	72	74	76
Ovens built	7,211	8,208	9,283	10,176	10,543
Ovens building	731	654	592	101	200
Coal used, short tons	3,367.856	4,018,782	4,628,736	5,355,380	4,829,054
Coke produced, short tons	2,205,946	2,639,002	3,043,394	3,552,402	3,192,105
Total value coke at ovens	$3,948,643	$4,301,573	$4,473,789	$4,049,738	$3,607,078
Value coke at ovens per ton	$1.79	$1.63	$1.47	$1.14	$1.13
Yield of coal in coke, per cent	65½	65⅔	65¾	66⅓	66.1

Irwin-Latrobe (*Pennsylvania railroad*) *district.*—Following the line of the Pennsylvania railroad from Larimer's station to Blairsville are quite a number of coke ovens. To the coal used in a portion of these, that from the upper portion of the Connellsville trough, allusion has already been made. The coke is inferior to that of the same basin further south. As showing the character of the coal in this part of the Connellsville basin, and of the coke made from it, the following analyses are given, which have been furnished by Mr. Benjamin Crowther, of the Isabella Furnace Company:

Analyses of Coketon (*Pennsylvania*) *coal.*

	Top of vein.	Bottom of vein.
	Per cent.	*Per cent.*
Bituminous matter	25.52	18.18
Fixed carbon	70.91	60.57
Ash	3.34	20.08
Sulphur	.23	1.17
	100.00	100.00

Analyses of Coketon (*Pennsylvania*) *coke.*

	Unwashed.	Washed.	
		No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*
Moisture and volatile matter	1.26	....	....
Fixed carbon	86.58	89.15	83.93
Ash	10.67	9.65	14.80
Sulphur	1.49	1.20	1.27
	100.00	100.00	100.00
Silica in ash	....	4.67	6.12

Mr. Crowther states that the No. 1 coke, from washed coal, is about the average result when the washer is working right. A comparison of the above analyses with those of the Connellsville coal and coke from the neighborhood of Broad Ford will show the difference in the character of the coal and the similarity of the coke from the washed coal.

This variation in the Connellsville coal seems to have been discovered at an early day in the history of coke manufacture, for the coke making area is confined to that portion of the trough which lies south from Sewickley creek, and the works are by no means important until one comes near to Jacob's creek. Thence southward to near Uniontown, in Fayette county, the eastern outcrop of the bed is lined with coke ovens. There appears to be prejudice in favor of the eastern outcrop. Although manufacturers claim that the coal on the western outcrop is somewhat inferior, facts do not seem to justify this prejudice. The extensive coke works near Dawson, on the Youghiogheny river, are upon the extreme western outcrop, but the coke made there is not inferior to any made along the eastern outcrop from Mount Pleasant to Lemont furnace.

West of the northern extremity of the Connellsville basin is a small trough known as the Greensburg, in which some coke is made.

Still following the line of the Pennsylvania railroad westward, the Irwin basin is less than 10 miles distant from the Greensburg, and includes the mines of the Penn Gas-Coal Company and the Westmoreland Coal Company, so well known for the production of coal of excellent gas-making qualities. The coal from the Pittsburgh bed in this portion of the Irwin trough makes an excellent coke, and contains, except in very rare cases, but little sulphur and a very low percentage of ash. The coal, however, is much harder than the Connellsville, and will bear shipping, which the Connellsville, as a rule, will not, being too friable. The coal of this trough also contains a large proportion of volatile combustible matter, and consequently the percentage of coke per ton of coal is much less than in the Connellsville region. For these two reasons, and to utilize what would otherwise be not only a waste product but one very inconvenient to dispose of, but little lump coal is used in coking, most of the coke being made from slack.

The largest works in this trough is that of Carnegie Brothers & Co., limited, who have a large number of ovens, with necessary washers, near Larimer station, on the Pennsylvania railroad; washed slack, chiefly from the mines of the Westmoreland Coal Company and the Penn Gas-Coal Company, being used. This coke is of good quality, in some respects equal to the Connellsville and lower in ash, and has been used in Pittsburgh furnaces with good results. An average of three analyses of the Penn Gas-Coal Company's coal, made by Mr. A. S. McCreath, chemist of the Pennsylvania Geological Survey, is as follows:

Analysis of coal from the Irwin-Latrobe district (Penn Gas-Coal Company).

	Per cent.
Water	1.427
Volatile matter	37.980
Fixed carbon	54.598
Sulphur	.638
Ash	5.357
	100.000

From Messrs. Carnegie Brothers & Co. we have the following analyses of the slack, both washed and unwashed, and of the coke made from the same. It will be noted, on comparing the analysis of the unwashed slack with that of the coal above given, that the amounts of sulphur and ash are both very much higher in the unwashed slack than in the coal, while the volatile matter is somewhat lower. By washing, the slack is made to very nearly equal in purity and contents the unwashed coal.

Analyses of washed and unwashed slack and coke from the same (Irwin-Latrobe) district.

	Slack.		Coke.
	Unwashed coal.	Washed coal.	
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	56.57	54.88	88.240
Volatile matter	31.68	38.13	1.384
Ash	11.08	6.98	9.414
Sulphur	1.26	.96	.962
	100.59	100.95	100.000

The following are the statistics of the manufacture of coke in the Irwin-Latrobe district from 1880 to 1884:

Statistics of the manufacture of coke in the Irwin-Latrobe (Pennsylvania railroad) district, 1880 to 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	8	10	11	11	11
Ovens built	757	986	1,118	1,118	1,118
Ovens building	0	0	0	0	0
Coal used, short tons	319,927	588,924	650,174	668,882	496,894
Coke produced, short tons	229,433	343,728	375,918	389,053	294,477
Total value coke at ovens	$397,945	$ 548,362	$536,503	$422,174	$311,665
Value coke at ovens per ton	$1.73	$1.60	$1.43	$1.08	$1.06
Yield of coal in coke, per cent	59	58	58	58	59

Alleghany Mountain district.—The most important coking district in western Pennsylvania next to the Connellsville is the Alleghany Mountain, which district includes that part of Blair and Cambria counties lying in the First bituminous basin, along the sides and near the summit of the Alleghany mountains. This basin extends both north and south of these counties, but the coke made from its coal was all made in the counties named. The coal in the different sub basins of these counties differs widely in its coking qualities. In the eastern portion of the region, on the eastern slope of the mountains, near the summit, it cokes readily in the beehive oven, forming a hard, silvery coke, but little, if any, inferior to the Connellsville. West of the summit, on the slope, beehive ovens are also used, but the coke, which is from a different bed of coal, is not so good as that at Bennington and other localities in Blair county. Still west of this a few miles, at East Conemaugh, pits were used and a good coke made, while a short distance farther west the coal is so dry burning that the Belgian oven is employed. This distance, say from Altoona to Johnstown, less than 40 miles, thus becomes one of the most interesting coking districts in the country. The coal varies from a true coking coal, making in the beehive oven an admirable blast-furnace coke, to a dry-burning coal that cannot be coked to advantage in the beehive oven, requiring the heat of the Belgian oven to coke it properly. In this same district could recently be studied the three typical methods of coking—in pits, in beehive ovens, and in Belgian ovens. The experiments made for the Cambria Iron Company by Mr. John Fulton, its mining engineer, in the use of different coals and methods of coking, as well as those relating to the value of cokes, have been the most careful and thorough of any made in this country. They have already been of great value, and must be of increasing importance.

The coal most extensively used for coke, as well as that making the best coke in the district, is bed B of the Geological Survey. Analyses of this coal as it is mined at Bennington, in Blair county, where it is called the Miller seam, and the coke from it, are as follows:

Analyses of coal and coke from bed B, Alleghany Mountain district.

	Coal.	Coke.
	Per cent.	*Per cent.*
Water	1.400	
Volatile matter	27.225	
Fixed carbon	61.843	87.58
Ash	6.930	11.36
Sulphur	2.602	1.06
	100.000	100.00

The coal is semi-bituminous, has a shining luster, and contains considerable pyrites. In the vicinity of Bennington the bed is about 3½ feet thick. All of the coke made in Blair county (beehive ovens being used) is from this seam, and closely resembles the Connellsville, is sonorous, cellular, and tenacious, reasonably pure, and has great calorific vigor.

On the western side of the summit of the Alleghanies, at Lilly's station, in Cambria county, coal from bed E, commonly known as the Upper Freeport bed, is coked. An average analysis of this coal at this point is as follows:

Analysis of Upper Freeport coal, Cambria county.

	Per cent.
Water	.715
Volatile matter	12.250
Fixed carbon	70.518
Sulphur	1.459
Ash	5.058
	100.000

This coal has a bright, shining luster, is rather friable, and contains numerous thin partings of mineral charcoal and pyrites. Coke was made from this coal in open ricks until December, 1879, when some beehive ovens were put in operation.

The Lilly's Station mine is in the Wilmot sub-basin of the First bituminous basin. A short distance west an anticlinal rises, which separates this sub-basin from the Johnstown sub-basin, where bed E is again used at the East Conemaugh ovens. This coal is reasonably pure, is low in ash but high in sulphur, and makes a dense coke. It is also low in volatile matter.

At Johnstown, bed E, or the Upper Freeport, the same bed as is coked at Lilly's station and East Conemaugh, has been coked in Belgian ovens. An analysis of this coal by T. T. Morrell, chemist, is as follows:

Analysis of Upper Freeport coal, East Conemaugh.

	Per cent.
Moisture	.160
Volatile matter	18.630
Fixed carbon	74.950
Ash	4.860
Sulphur	1.400
	100.000
Phosphorus	.011

The statistics of the manufacture of coke in the Alleghany Mountain and Somerset district for the years from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in the Alleghany Mountain and Somerset district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	8	9	10	10	12
Ovens built	291	371	481	532	614
Ovens building	0	0	0	0	0
Coal used, short tons	201, 345	225, 563	284, 544	206, 343	241, 459
Coke produced, short tons	127, 525	144, 430	179, 580	135, 342	156. 290
Total value coke at ovens	$289, 929	$329, 198	$377, 286	$240, 641	$203, 213
Value coke at ovens per ton	$2. 27	$2. 28	$2. 10	$1. 78	$1. 30
Yield of coal in coke, per cent	63	64	63	68	65

Of the above ovens one hundred and two were Belgian, and, in addition to the ovens given, some pits were reported as used in the manufacture of coke.

Snow Shoe district.—The Coal Measures of Centre county are confined to the four northern townships, and are the southeasterly continuation of those of Clearfield county. The Snow Shoe basin, from the coals of which the Centre county coke is made, is a part of the First basin of the Pennsylvania Geological Survey. It is some 8 miles wide, though only about one-half is occupied by the Coal Measures. The seams worked are chiefly the Lower and Upper Kittanning and the Upper

Freeport, or beds B, C, and E. The coals and cokes are quite pure, as the following analyses will show:

Analyses of Snow Shoe basin coals and cokes.

	Coal.		Coke.		
	Snow Shoe Coal and Coke Company.	Bed E.	Snow Shoe Coal and Coke Company.	Bed E.	Bed E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	70.416	68.937	82.626	90.672	89.208
Volatile matter	24.560	25.580	2.950	.564	.468
Ash	3.410	3.590	12.330	7.910	9.444
Sulphur	.964	.613	1.104	.704	.770
Water	.650	1.280	.990	.150	.110
	100.000	100.000	100.000	100.000	100.000

The first coke of which an analysis is given was made in the open air, from crushed slack; the second and third in ovens, from crushed and washed slack.

Some small amounts of coke have been made in pits in that part of Clearfield county adjoining Centre county, but for some years none has been made. The coke made in the northern part of the county will be included in the Low Grade district.

The following are the statistics of the manufacture of coke in the Snow Shoe district of Pennsylvania for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Snow Shoe district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	2	1	1	1
Ovens built	0	50	50	60	60
Ovens building	0	0	0	0	0
Coal used, short tons	200	20,025	25,000	26,500	33,000
Coke produced, short tons	100	13,350	17,160	18,696	23,431
Total value coke at ovens	$200	$22,695	$27,406	$28,044	$32,849
Value coke at ovens per ton	$2	$1.70	$1.60	$1.50	$1.40
Yield of coal in coke, per cent	50	67	69	71	71

Broad Top region.—Included in this district are all the ovens located in Bedford and Huntingdon counties. The Broad Top coal region is a detached field, showing great variations in thickness and quality of its coal, and presenting obstacles to mining which are quite serious to those accustomed to the regular coal beds of western Pennsylvania. The beds, however, are of great economical importance, the coal being of decided excellence and the coke second only to Connellsville. The beds mined are chiefly the Kelly, or E (Upper Freeport), and the Fulton, or A.

In this region there are 453 coke ovens, of which 205 are Belgian or flue ovens, the rest being beehive. The latter seem best adapted to the coals of this district, the coke made being hard, bright, and cellular. The yield of coal in coke varies in actual practice from 63.3 per cent. to as low as 57.4 per cent. These are averages for five years. Experimentally the yield would be greater than this—say 67 per cent.

Regarding coking in this region, Mr. William Lauder, the manager of the Kemble Coal and Iron Company, has furnished the following interesting statement: "The manufacture of coke was begun in the Broad Top region in 1867–'68, the Kemble Coke and Iron Company having erected forty-eight beehive ovens in connection with their blast furnace. These in 1868–'69 were supplemented by forty more, making a plant of eighty-eight ovens similar in all respects to those in the Connellsville region. These have been in continuous operation ever since. As the coke was for their own use, the company desired to secure the best results, and many experiments were made to improve its quality. Without entering into details, I may note some of the experiments that proved unsuccessful:

"1. Washing coal: A large and expensive washer, a modification of Berard's, was erected. This removed a large amount of dirt—fully 13 per cent. of the coal washed—but the coal, while clean, produced irregular results in the ovens. The cause of this was found to be that in removing the slate the richest bitumen adhered to it and was lost, and this deprived the coal of part of its coking qualities. The amount of bitumen varied as the slate was greater or less in amount, and caused an irregular quality of coke. After using the washer a number of years it was abandoned.

"2. Coking in Belgian or Gobiet ovens: B. A. Knight, president of the Huntingdon and Broad Top railroad, through the representations of the owner of the Gobiet ovens, was induced to erect three of these adjacent to and connected with our beehive ovens. The result of a careful trial was conclusive that this type of oven was not suitable for our coal. The great yield claimed was not borne out in furnace results. The weight of the coke seemed to justify the asserted yield of 75 per cent., but the greater part of the increased yield was water, and coke more similar to a block of wood than beehive coke. An analysis of the coke at that time showed carbon 87.49 per cent., and of beehive coke made at same time and from same coal, 89.13.

"Belgian ovens and modifications of them have been built in the region, but in no instance have they made as good coke as the beehive, and the expense of repairs has proved to be so great that the cost of making coke is less in the beehive.

"To obtain good coke it is necessary to have a good coal and extra care in mining it. Washing and any manipulation to remove dirt are costly, and in our opinion injurious. The same capital invested in development and purchase of good coal land is much more productive. Aside from the loss, which would average 10 per cent. in weight of slate, etc., in washing, the labor costs, say, 10 cents per ton of coal. An acre of coal with us will give about 4,480 tons. This would be $448 per acre, added to the first cost of the property. In the majority of the Pennsylvania coal fields a far less amount would obtain the best coal in the region.

"The yield of the coal in coke runs in an exact test 70 per cent. A test made some time ago gives the following results:

"Seventeen thousand five hundred pounds of coal gave:

	Pounds.	Per cent.
Coke	12,065	70.35
Ash	745	4.34
Loss	....	25.31

"In the above test all the products were carefully handled and accurately weighed. This yield would not be carried out in practice. Our experience for several years shows our yield to be 62 per cent.; that is, the weight of coke charge in the furnace was 62 per cent. of all the coal used in the coke ovens. This is a good yield, taking into consideration rehandling, ovens lost, etc. The analysis of the coke, as determined by Mr. Fulton, of the Cambria Iron Company, who fully treats of the subject in Report L of the Pennsylvania State Geological Survey, is as follows:

	Per cent.
Carbon	89.28
Ash	9.66
Sulphur	1.06
	100.00

"Sulphur volatilized in coking, 56 per cent. In the same report he gives an analysis of Connellsville, as follows:

	Per cent.
Carbon	87.46
Ash	11.32
Sulphur	.69
	99.47

"Showing an increase of carbon in our coke of 18.02 per cent. In another table he shows the percentage of cells in Broad Top coke to be 41.73 per cent., and in Connellsville 38.47 per cent., an increase in favor of our coke of 3.26 per cent. But he shows also that the compressive strength per cubic inch, in pounds, in Broad Top coke, is 240, while in Connellsville it is 284, showing the latter to be the harder coke. Practical results of Broad Top coke show that it is equal to the best Connellsville. It might not stand transportation and handling as well as the latter, but for home use it is as good a fuel as can be got in the State.

"The cost of making coke depends on the situation of the ovens and whether the coal is owned or leased. At the present rates of mining and labor I have not the least means of ascertaining accurately the cost of labor per ton of coke, but I infer it to be about 45 cents. To this must be added the value of the coal, which varies. At present prices it is impossible, except at a few mines favorably located, to deliver coal on the cars for less than 65 cents per long ton. To have any return for exhaustion of property and interest on investment, 10 cents should be added, making the coal 75 cents. Then—

1.6 tons of coal, at 75 cents	$1.20
Coking	45
	1.65 gross

"This is at the ovens, at the mines. It is safe to say that at present rates of mining coke can be made profitably for $1.75 per long ton, or $1.56 per short ton.

"In the analyses given of coke it is understood that they are of Riddlesburg coke, which, without any reflection upon other coke made in this region, is supposed to be the best. The coke varies in coal of the same seam mined in different localities. The percentage of ash as given by Mr. Fulton appears low. To test the subject thoroughly we have, within a few days past, made another analysis by taking the samples after dark, when it was impossible to distinguish them. Of a wheelbarrow so taken and crushed and tested the percentage of ash was 12.03. This is from unwashed coal. Mr. Fulton's sample was taken from washed coal, and the difference probably arises there."

The statistics of the production of coke in this region in the years from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in the Broad Top region, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	5	5	5	5	5
Ovens built	188	188	293	343	453
Ovens building	105	105	50	110	0
Coal used, short tons	92,894	111,593	170,637	220,932	227,954
Coke produced, short tons	51,130	66,560	105,111	147,154	151,959
Total value coke at ovens	$123,748	$167,074	$215,079	$271,692	$264,569
Value coke at ovens, per ton	$2.40	$2.51	$2.05	$1.84	$1.74
Yield of coal in coke, per cent	55	59	62	66	66

The value given in the above table is in some cases the cost at the ovens; in others, an assumed price over cost. So little of the coke is sold that no market price can be given. The prices for 1880 range from $2.25 to $3.05; for 1881, from $2.25 to $2.95; for 1882, from $1.64 to $2.86; for 1883, from $1.53 to $2.61; for 1884, from $1.48 to $2.61 per ton.

Pittsburgh district.—In this district are included the coke ovens in Allegheny and Washington counties and those on the Monongahela river in Fayette county. The coal burned is slack from the Pittsburgh bed, little or no lump coal or run of the mine being used except at one of the Monongahela mines.

As is stated elsewhere, the so-called Connellsville coking coal is without doubt a portion of the Pittsburgh bed. The coal of this bed at Pittsburgh, however, is not as thick nor does it make as good a coke as the Connellsville. While the coke is as pure—indeed, it is freer from ash—its physical properties are not as good. It is too porous and not as strong a fuel. In addition to this the Pittsburgh coal is a harder coal and will stand transportation, as the Connellsville will not, and is more valuable for other purposes than for coke making. The Pittsburgh coal in this district is chiefly from what is known as the lower division, the roof division as a rule being inferior. It is from 3 feet 6 inches to 9 feet thick, and contains three persistent partings, usually thin. These divide it into four benches, known as the "upper," "bearing-in," "brick," and "lower." The "upper bench" is the thick bench, and usually yields the best coal. The coal from the lower division of the Pittsburgh bed is somewhat brittle, coking, rich in volatile combustible matter, and contains a variable percentage of sulphur. The amount of coke made varies not only with the demand for coke, but with the demand for slack for manufacturing purposes. But few of the mines, especially those on the Monongahela river, have coke ovens, and much of the slack from these is sold to the coke ovens of Pittsburgh. All of the ovens in this district are beehive, except eighty at a works in Pittsburgh, which are Belgian.

What has been termed Monongahela River coke is that made in the Fourth and Sixth pools. As is noted above, considerable slack from the First, Second, and Third pools is coked in ovens in Pittsburgh and vicinity. At Cat's run, in the Sixth pool, sixty ovens were built in 1877. Nearly the whole product of the mine was coked in 1880 and 1881, and shipped to Ironton, Ohio. The coke was an excellent fuel, but contained small fragments of slate that injured its appearance. When washed the coke was quite pure. There are three other coke works in these pools, all using slack. The coke from the Umpire mines analyzed as follows:

Analysis of Monongahela River, Pennsylvania (Umpire mines), coke.

	Per cent.
Fixed carbon	86.990
Ash	11.899
Sulphur	.798
Water	.313
	100.000

The statistics of the manufacture of coke in the Pittsburgh district are as follows for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Pittsburgh district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	21	21	21	20	20
Ovens built	534	538	557	542	535
Ovens building	0	0	0	0	0
Coal used, short tons	194, 393	178, 509	114, 956	119, 310	97, 367
Coke produced, short tons	105, 974	96, 310	64, 779	66, 820	53, 357
Total value coke at ovens	$254, 500	$206, 965	$134, 378	$126, 020	$99, 911
Value coke at ovens per ton	$2. 40	$2. 15	$2. 07	$1. 89	$1. 87
Yield of coal in coke, per cent	55	54	61	56	55

Washington county.—In Washington county there are three coke works, with forty-three ovens. These are operated, as are all of those in what has been termed the Pittsburgh district, to utilize the slack. When the slack can be sold at prices that are regarded as remunerative, it is not coked. When it is more profitable to burn it, it is sent to the ovens. The coal coked is from the Pittsburgh bed. The coke is used to a limited extent, if at all, in iron making, though, considering the character of the coal from which it is made, it is surprisingly compact. The statistics of the production of coke in Washington county are included in those of the Pittsburgh district.

Beaver district.—The coke industry in the Beaver district, which includes the counties of Beaver and Lawrence, is of but little importance. The ovens in Beaver county are located at three small coal mines, and are only nine in number. The Lower Kittanning coal is coked. The seam is 2 feet 4 inches, with a thin slate parting of 1 inch. There is quite a difference between the two benches. The upper is a hard, dull, open-burning coal, and contains some pyrites, while the lower is a bright, oily, soft, coking coal. Much of the lower coal comes out as slack and is coked, producing a firm, silvery, cellular coke, which is used at the Beaver Falls manufactories. The analyses of the Beaver Falls coal and coke from the lower bench are as follows:

Analyses of Beaver Falls (lower bench) coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Fixed carbon	54. 619	84. 727
Volatile matter	38. 110	. 633
Ash	4. 080	12. 636
Sulphur	. 791	1. 994
Water	2. 400	. 010
	100. 000	100. 000

In Lawrence county there are two coke works, neither of which was in operation in 1884, and one of which has been idle the entire time covered by this report. This latter works was built to utilize the slack from the coal mines in the vicinity of New Castle, but difficulty was found in keeping the ovens supplied with slack, and they have been idle, as noted. The coal coked at the Wampum furnace was the Darlington coal, or Upper Kittanning, the most important and persistent of the Lawrence County coals of the Lower Productive series. Both of the coke works in Lawrence county are much dilapidated, and would require extensive repairs before they could be again put in operation. The Wampum ovens are regarded as abandoned.

The following are the statistics of the manufacture of coke in the Beaver district for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Beaver district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	5	5	5	5	4
Ovens built	106	106	106	107	89
Ovens building	0	0	0	0	0
Coal used, short tons	8, 013	6, 887	11, 699	19, 510	2, 250
Coke produced, short tons	4, 880	4, 333	7, 960	12, 395	1, 390
Total value coke at ovens	$10, 150	$9, 013	$15, 124	$21, 062	$2, 168
Value coke at ovens per ton	$2. 08	$2. 08	$1. 90	$1. 70	$1. 56
Yield of coal in coke, per cent	61	63	68	64	62

Alleghany Valley district.—In this district are included the ovens of Armstrong and Butler counties and those at one works in Clarion county.

In Armstrong county there are three coke works, supplying coke to blast furnaces connected with them. At Kittanning the Kittanning Iron Company, limited, has sixty-six ovens, the only ones in the county, the coke at the other two works being made in open ricks on the ground. At Kittanning the Freeport Upper seam is coked (the coal being first washed), producing a fuel that answers the requirements of the furnace practice. This same seam is coked both at Stewardson furnace and Mahoning furnace. The coking is badly done, in open-air ricks, requiring from eight to twelve days in the operation, according to the state of the weather. The coke is tender, but the furnaces in which it is used are small, and great burden-carrying powers are not necessary. Analyses of the coal and coke are as follows:

Analyses of Upper Freeport coal and coke from Armstrong county, Pennsylvania.

	Stewardson coal.	Mahoning coal.	Kittanning coke (washed).
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	55. 545	54. 996	87. 22
Volatile matter	35. 520	34. 810	....
Ash	6. 630	7. 690	11. 43
Sulphur	. 835	1. 054	1. 23
Water	1. 470	1. 450	....
	100. 000	100. 000	99. 88

In Butler county there are three coke works, one of which is of little importance. Each of the other two has fifty ovens. One bank of fifty ovens has been in operation since 1882. The other was built during 1884, only beginning operations in December. But little information could be secured as to the coke or coal. The seam used is perhaps the Clarion. The coke finds a market in northwestern Pennsylvania and eastern Ohio, at foundries, iron works, etc.

The most important of the coke-producing districts of the Alleghany valley is in Clarion county. In this county there are three coke works, all situated on Red Bank creek, the dividing line between this and Armstrong county. The oldest of these is at the Red Bank furnace, situated at the junction of the Alleghany river and Red Bank creek. At these ovens coke is made from the Freeport Upper coal, which is found in what is termed a 4-foot bed, but does not average that thickness. There are sharp local variations, the coal in some places being but 2½ feet thick. An analysis of the coke is as follows:

Analysis of coke made at Red Bank furnace, Clarion county, Pennsylvania.

	Per cent.
Fixed carbon	88.360
Volatile matter	1.106
Ash	9.228
Sulphur	1.076
Water	.230
	100.000

The coke is dull gray and of an open structure, with small masses of slate.

Statements regarding the ovens near Fairmount City, the other two works in this county, will be found under the head of the Low Grade district.

The following are the statistics of the manufacture of coke in the Alleghany Valley district of Pennsylvania for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Alleghany Valley district, Pennsylvania, 1880 to 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	5	5	6	6	7
Ovens built (*a*)	97	109	159	159	209
Ovens building	0	0	0	0	0
Coal used, short tons	45,355	55,676	76,000	64.810	55,110
Coke produced, short tons	23,470	29.650	41,897	34,868	31,430
Total value coke at ovens	$49,068	$64,661	$80,294	$62.982	$54,859
Value coke at ovens per ton	$2.10	$2.18	$1.92	$1.81	$1.75
Yield of coal in coke, per cent	52	53	55	54	57

a Two establishments have no ovens, burning their coke in ricks.

Low Grade or Bennett's Branch district.—The Low Grade division of the Alleghany Valley railroad, or the Bennett's branch, as it is sometimes called, runs northeasterly from Red Bank junction to Driftwood, through Clarion, Jefferson, Clearfield, and Cameron counties. Along the line of this road there are six coke works, two in Clarion county.

one in Jefferson, two in Clearfield, and one in Cameron. Most of these works use only slack.

The two works in Clarion county make coke from the Lower Freeport bed, the seam averaging 6 feet. The slack is mixed with considerable slate and fireclay, and requires careful washing. The Stutz washer is used. The ovens at Fairmount City were erected in 1879; those in Porter township in 1882. The following are analyses of the coal and coke from Fairmount City:

Analyses of coal and coke from Fairmount City, Pennsylvania.

	Unwashed slack.	Washed slack.	Coke.
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	51.397	54.223	85.777
Volatile matter	35.130	35.825	.623
Ash	10.225	7.340	11.463
Sulphur	1.988	1.312	2.107
Water	1.260	1.300	.300
	100.000	99.900	100.270

The coke is hard, bright, silvery, of rather an open structure, with small masses of slate included, takes the blast easily, and has a good reputation for both foundry and blast-furnace use.

In Jefferson county there is one works, with thirty-one ovens, coking slack from the Freeport Lower bed. Analyses of the coal and coke are as follows:

Analyses of Jefferson County, Pennsylvania, coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Fixed carbon	62.524	88.95
Volatile matter	30.800	1.42
Ash	4.800	7.95
Sulphur	.776	.90
Water	1.100	.78
	100.000	100.000

The coking qualities of this coal are not the best, but fair.

In Clearfield county there are two coke works, one in the Reynoldsville gas-coal basin and the other in the Third bituminous coal basin. At the former, slack from the Freeport Lower coal is used. The bed is 6 feet thick, at times 8 feet, the coal analyzing as follows:

Analysis of Clearfield County (Low Grade) coal.

	Per cent.
Fixed carbon	59.904
Volatile matter	32.450
Ash	5.400
Sulphur	1.296
Water	.950
	100.000

The coal is firm, bright, and bears transportation well. Owing to a thin parting of soft slate near the bottom of the seam, and which becomes broken and mixed with the fine coal in the operation of undercutting, it was found desirable to wash the slack or fine coal in order to remove this slate, both for coking and smithing purposes, and a washer with two compartments was built several years ago, but in consequence of increased production is now too small and will soon have to be replaced by a larger machine. The coke is bright, of great calorific energy, and capable of sustaining a heavy burden. Coming as it does in direct competition with that manufactured in the Connellsville region, its finding and holding a place in market is ample proof of its excellent quality.

Analysis of Clearfield County (Low Grade) coal.

	Per cent.
Fixed carbon	61.653
Volatile matter	31.060
Ash	4.950
Sulphur	1.487
Water	.940
	100.090

The coal does not swell much in coking, and forms a hard, compact coke, with a metallic luster. At this works the run of the mine is coked, all being crushed and washed.

There is one coke works in Cameron county, which, however, has not been operated since the fall of 1883, coke production having been stopped at that time owing to the low price.

The following are the statistics of the manufacture of coke in the Low Grade district of Pennsylvania for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Low Grade district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	3	4	5	6	7
Ovens built	117	125	177	229	321
Ovens building	0	2	0	0	0
Coal used, short tons	45,055	99,489	87,314	76,580	159,151
Coke produced, short tons	28,090	44,260	44,709	37,044	78,646
Total value coke at ovens	$46,359	$80,785	$80,339	$65,584	$113,155
Value coke at ovens per ton	$1.65	$1.85	$1.80	$1.77	$1.44
Yield of coal in coke, per cent	62	44	51	48	49

Blossburg district.—The Appalachian coal field at its northern extremity breaks into a number of small, detached coal basins. The best known of these is the Blossburg, in Tioga county, a canoe-shaped synclinal some 20 miles long and 3 wide. From the slack coal produced in mining in this basin considerable coke is made, there being in this county, at the close of 1884, 344 ovens built and the foundations and walls for 32 more. The first attempts, made some years since, to coke the Bloss coal were failures, and it was generally agreed that it could not be successfully coked. Some nine or ten years since more careful and skillful experiments were made, demonstrating that the slack coal, properly washed, would produce in the beehive oven a firm, coherent, ringing coke of fair character and strong enough to bear a furnace burden of 60 or 80 feet.

Coke works have been successfully operated during all the years covered by this report. Slack both from the Bloss bed (Upper Kittanning) and the Seymour bed, which lies some 150 feet above the Bloss, is used. The Seymour bed is 3 to 3½ feet thick. The coal is semi-bituminous, bright and shining, but very tender, carrying numerous thin partings of iron pyrites and a large amount of mineral charcoal. The Bloss coal is freer from sulphur than the Seymour. It is very tender and easily broken into irregular, cubical pieces. It is in three benches. The middle bench sticks to the bone coal beneath so closely "that it is necessary to allow the miner to send the latter out, and it is taken out and cleaned at the shutes. This is done on screens over which the coal passes, and more or less of this bone is broken up in the operation and falls in among the fine coal. It is from the fine coal that coke is now being made. This will explain why the coke from No. 2 drift, or Bloss vein, shows so much impurity in the form of small pieces of slate and bone. This is now taken out by washing." The following are analyses of the Bloss and Seymour coals and cokes from different mines in various parts of the field:

Analyses of Bloss and Seymour, Pennsylvania, coals.

	Bloss.					Seymour.
	Upper bench.	Middle bench.	Lower bench.	Run of mine.	?	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	71.697	64.306	63.428	71.847	69.655	71.574
Volatile matter	20.755	20.640	18.790	20.240	21.474	21.586
Ash	5.335	13.200	16.070	5.105	7.065	4.753
Sulphur	1.023	.914	.602	.548	.872	.907
Water	1.190	.940	1.110	2.260	.911	1.180
	100.000	100.000	100.000	100.000	99.977	99.900

Analyses of Bloss and Seymour, Pennsylvania, cokes.

	Bloss.					Seymour.	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	83.371	83.922	83.579	80.927	85.073	84.760	90.650
Volatile matter	.845	.572	.550	1.732	.838	.722	.625
Ash	14.550	14.587	15.105	15.427	13.288	13.345	7.655
Sulphur	.644	.679	.686	.764	.779	.998	.850
Water	.590	.240	.080	1.150	.022	.175	.220
	100.000	100.000	100.000	100.000	100.000	100.000	100.000

The coke is made chiefly to utilize the slack. This accounts for the much larger percentage of ash in the coke than in the coal. The following are the statistics of the manufacture of coke in the Blossburg district for the years from 1880 to 1884:

Statistics of the manufacture of coke in the Blossburg district, Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	1	1	2	2
Ovens built	200	200	200	344	344
Ovens building	0	0	0	0	32
Coal used, short tons	72, 520	88, 055	100, 119	71, 028	62, 365
Coke produced, short tons	44, 836	56, 085	64, 526	44, 690	39, 043
Total value coke at ovens	$134, 500	$168, 250	$193, 500	$122, 450	$93, 763
Value coke at ovens per ton	$3	$3	$3	$2. 74	$2. 40
Yield of coal in coke, per cent	62	64	64	63	63

Total coke production in Pennsylvania.—Consolidating the statistics of the different districts of Pennsylvania given above, the following are the statistics of the production of coke in Pennsylvania from 1880 to 1884:

Statistics of the manufacture of coke in Pennsylvania, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	124	132	137	140	145
Ovens built	2, 501	10, 881	12, 424	13, 610	14, 285
Ovens building	836	761	642	211	232
Coal used, short tons	4, 347, 558	5, 393, 503	6, 149, 179	6, 823, 275	6, 204, 604
Coke produced, short tons	2, 821, 384	3, 437, 708	3, 945, 034	4, 438, 464	3, 82 , 128
Total value coke at ovens	$5, 255, 042	$5, 898, 579	$6, 133. 698	$5, 410, 387	$4, 783, 230
Value coke at ovens per ton	$1. 86	$1. 70	$1. 55	$1. 22	$1. 25
Yield of coal in coke, per cent	65	64	64	65	62

TENNESSEE.

The coal fields of Tennessee, which are a continuation of the great bituminous deposits of Pennsylvania and West Virginia, are computed to cover an area of 5,100 square miles. These fields extend through the State from northeast to southwest, are coëxtensive with the Cumberland table lands, about one half of the area being in middle Tennessee and the other half in east Tennessee, and form an irregular quadrilateral 71 miles wide at the northern border and 50 at the southern. It is not within the province of this paper to describe this field, except so far as it is necessary to understand the conditions under which coke is produced. The best idea of the location of the ovens can be had from Chattanooga. In the southern half of this coal field, on the eastern side, is a deep fissure, canoe-shaped, with sharp escarpments rising from 800 to 1,000 feet above the valley, through which the Sequatchie river flows. By this fissure the southern half of the coal field is divided into two distinct arms. The eastern is about 12 miles wide and 70 long, and is known as Walden's ridge. The western arm is about 35 miles wide. These two unite above the head of the Sequatchie valley. Along Walden's ridge, taking them in order northeast from Chattanooga, are the ovens of Hamilton, Rhea, Roane, and Anderson counties; and northwestward from Anderson, almost on the extreme western outcrop of the coal, those of Scott county. Returning to the southern line of the State, in the western arm are the mines of Grundy county, and south of Chattanooga, on an extension of Walden's ridge known as Raccoon mountain, are the Etna mines of Marion county. North of these, and north of the Tennessee river, are the Victoria mines, at South Pittsburgh, in the same county.

At present the most important coke-producing district in the western division is at Tracy City, Grundy county, on the Little Sequatchie. The coal mined is that known as the Sewanee. This bed is in what are termed by Professor Killebrew the Upper Measures, and by Professor Colton the Middle Measures, and is supposed by Professor Killebrew to correspond with bed B (the Miller of the Lower Productive Measures) of the Pennsylvania Geological Survey, which at Bennington, in the Alleghany Mountain region, makes such excellent coke. The Sewanee bed is to Tennessee what the Pittsburgh is to Pennsylvania and the Pratt to Alabama. It will average 4½ feet in thickness, its largest development being 10 feet 4 inches, its smallest 2 feet, and varies in its characteristics and constituents in different localities. As mined at Tracy City, the coal is semi-bituminous, conchoidal in fracture, reasonably low in ash, and almost wanting in sulphur. It is a very weak coal, having the same tendency to disintegrate upon exposure to the air that is so noticeable in Connellsville coal. At the ovens in Tracy City the coke is made in part from slack, which accounts for the much larger percentage of ash in the coke than in the coal.

Analyses of the Sewanee coal and coke are as follows:

Analyses of the Sewanee, Tennessee, coal.

	No. 1. (*a*)	No. 2. (*b*)	No. 3. (*c*)
	Per cent.	*Per cent.*	*Per cent.*
Water			1.6
Volatile matter	29.9	29.0	29.3
Fixed carbon	63.5	65.5	61.0
Ash	6.6	5.5	7.8
Sulphur	Trace.		Trace.
	100.0	100.0	99.7

a Analyst, H. T. Yaran. *b* Analyst, F. Zwicke. *c* Analyst, Robertson.

Analysis of Sewanee, Tennessee, coke.

[Analyst, W. S. Land.]

	Per cent.
Fixed carbon	83.364
Ash	15.440
Sulphur	.142
Undetermined	1.054
	100.000

At the Tracy City works of the Tennessee Coal, Iron and Railroad Company there were, at the close of 1884, 404 ovens built, with 175 more building. The coke is a fair furnace fuel and is in good demand at the blast furnaces of the State. Coke was first made here in 1868. In that year 107 tons were made. In 1873 but 1,243 tons were produced; in 1884, 100,935 tons. A washer was erected at these works, but the results obtained were not satisfactory, and it is not now used.

South of the Tennessee river, near the Alabama line, in Marion county, on an extension of Walden's ridge known as Raccoon mountain, are the Etna mines, the coke from which has a most enviable reputation for foundry purposes. The coke is made from the coal of what is known as the Kelly vein. The Kelly seam is frequently regarded as the equivalent of the Sewanee at Tracy City, and Prof. J. B. Killebrew, the commissioner of mines of Tennessee, shares in this opinion. It is asserted, however, by the Etna Coal Company, which mines the Kelly coal, that in appearance and general characteristics these two coals are as different as two coals of the same formation can well be, and samples of both seem to bear out this claim. In Professor Safford's Geology of Tennessee (pages 369–382) the difference between the two measures can be readily distinguished. Professor Colton has recently abandoned his belief in the identity of the two seams. The impression as to the identity of these two coals probably arises from the fact that both lie in the upper plateau of their respective regions. The Etna Coal Company claims, however, that the "Kelly," the "Oak Hill," and the "Slate" veins do not appear at any other point in this region. At Tracy City only eight veins are shown, while the Etna Coal Company claims eleven at its mines. A section of the Kelly mines shows two Conglomerates, while at the Sewanee mines there is only one.

The entire product of the Etna ovens is sold for foundry use, for which purpose it finds a ready market throughout the South. It is guaranteed to melt 8 to 1, and frequently melts 10 to 1. The only test made with it for blast-furnace use was in 1875. The Rising Fawn furnace blew in with it and ran four days on it before charging other coke. The record for this time was a fraction less than 64 bushels to a ton of iron, and the third day the entire product was No. 1 foundry.

The following are analyses of the coal and coke:

Analyses of Etna (Kelly), Tennessee, coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Fixed carbon	74.20	94.56
Volatile matter	21.10	....
Ash	2.70	4.65
Sulphur	.70	.79
Moisture	1.30	....
	100.00	100.00

The other works in Marion county is at Victoria, near South Pittsburgh. The seam resembles the Sewanee, but the coal requires washing.

Returning to Chattanooga, to the eastern or Walden's Ridge division, and going northwest, the coke works in Hamilton county, in which county Chattanooga is located, are those of the Soddy Coal Company, the Walden's Ridge Coal Company, and the Daisy Coal Company. At the latter, coke has been made in pits to a limited extent as an experiment, but with such good results that the company contemplates building 100 ovens. The coal analyzed 76 per cent. fixed carbon, 18 per cent. volatile matter, 4 per cent. ash, and 2 per cent. moisture, with 0.9 per cent. of sulphur. Coke has been made at the Soddy mines since 1880, from a vein which Professor Killebrew says has all the appearance of the main Sewanee. The coke is reported to be excellent.

In Rhea county, the next north of Hamilton, there are two coke works, one at Spring City, where no coking has been done since June, 1883, and but little prior to that, the enterprise proving unprofitable, and the other the works of the Dayton Coal and Iron Company, limited, an English company, with Sir Titus Salt at its head. This company is erecting two large coke furnaces at Dayton, one of which will be ready for blowing in July, 1885, and will make the coke for these at their ovens.

Northeast of Rhea county is Roane county, where coke has been made for a number of years for use at two of its furnaces, the Rockwood and Oakdale. The coal used at Rockwood by the Roane Iron Company appears to be of the Sewanee seam. The average thickness of the vein is 5 feet. The coal is easily mined and makes a hard and valuable but somewhat dense coke. Nearly the entire output of the mines is coked and used in the blast furnaces of the Roane Iron Company. Analyses of the coke and coal are as follows:

Analyses of Rockwood, Tennessee, coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Fixed carbon	63.74	84.187
Volatile matter	26.62	
Ash	7.82	14.141
Sulphur	.33	.182
Moisture	1.49	
	100.00	98.510

The coke is taken hot, in bogies, directly to the blast furnace.

The Oakdale furnace ovens, in the same county, Roane, were erected in 1873, the furnace making iron with raw coal and a little coke. The enterprise was a failure. In 1879 additional ovens were erected, and coke made until about April, 1883, when the furnace again blew out, since which no coke has been made. The coke is made from "Poplar

Creek coal," and is bright, clean looking, not as hard or as strong as Connellsville, and higher in sulphur, analyzing as follows:

Analysis of Oakdale, Tennessee, coke.

	Per cent.
Fixed carbon	90.06
Volatile matter	.95
Ash	8.76
Sulphur	1.643
Moisture	.27
	101.683

Another analysis shows but 5.94 per cent. of ash.

The company proposes resuming the manufacture of coke for the general market.

In Anderson county the Coal Creek coal is coked at a small works with four ovens. This is one of the largest coal-producing districts in Tennessee, and the coal makes a good coke, but little coke has as yet been made. The seam is about 5 feet workable coal. An analysis of the Coal Creek coal is as follows:

Analysis of Coal Creek, Tennessee, coal.

	Per cent.
Fixed carbon	57.52
Volatile matter	38.82
Ash	3.09
Sulphur	.20
Moisture	1.04
	100.67

In Scott county there are two coke works. The Glen Mary Coal and Coke Company, at Glen Mary, mines a very clean coal, and makes both furnace and foundry coke. The seam is from 3½ to 4 feet thick. The following are analyses of the Glen Mary coal and coke:

Analyses of Glen Mary, Tennessee, coal and coke.

	Coal.	Coke.
	Per cent.	*Per cent.*
Fixed carbon	61.66	90.20
Volatile matter	31.53	....
Ash	2.14	9.40
Sulphur	.881	....
Moisture	1.67	....
Phosphorus	.19	.40
	98.071	100.00

In a very interesting statement concerning coke in Tennessee, contained in his report on coal, Mr. Henry E. Colton says: "There is great need of improvement in the manufacture of coke in Tennessee. The largest establishment in the State is that of the Tennessee Coal, Iron and Railroad Company, at Tracy City, and the coal there used is the coking coal from which the largest supply for furnaces must be derived. It is identical in geological position with the coal next to Connellsville, the most largely used in Pennsylvania. In Mr. Fulton's paper it is shown that Bennington coal, in pits, gave 1 ton of coke to 1.67 of coal; that at Connellsville, 1.60 ton of coal make 1 ton of coke; and at Broad Top, 1.58 ton of coal make 1 ton of coke; while under the head of Tracy City mines it is seen that the superintendent states that he is only able to get 105 bushels of coke from 100 bushels of coal, equivalent to 1.90 ton of coal to a ton of coke. Mr. Williams, of the Soddy Coal Company, states that their yield is not over 110 bushels of coke to 100 of coal. Nor is it probable that much better results are reached at any other coke works.

"There is probably no doubt that the best coke yet made in the State was made from the Poplar Creek coal; this coal, however, yields only about 60 per cent. of coke, but it contains a minimum amount of ash. The highest range of ash in the coke from this coal is 5 per cent., while Connellsville has 9 to 11, Bennington 11, Blossburg 13, Sewanee 15, Pratt 11, Rockwood 14. Immediately in the neighborhood of the Poplar Creek coal, and also accessible to it by many miles of railroad, is the Sewanee seam, in the pitched strata of Walden's ridge; which by Professor Wormley's analysis has 63.1 per cent. of carbon, 27.7 per cent. of volatile matter, and 7.7 per cent. of ash. There can be no doubt that a mixture of these coals would make a coke coming at least very near to the perfect standard, and it is a valuable feature of the northeastern coal field that they are in such close proximity. The richness of one in the inflammable volatile matter supplies the heating power, which with the other alone might cause the loss of a part of its solid carbon.

"During the latter part of the year 1882 four ovens were erected at Coal creek to test the value of the coal of the seam there worked for coke making, and a considerable quantity of coke has been made, chiefly from slack; but the experiments cannot be said by any means to have been a perfect test. The coke has been used in Knoxville, mixed with Connellsville and also with Etna, and the founders speak well of it. There is no reason why it should not make at least as good coke as is made at Larimer station, on the Pennsylvania railroad, from the washed slack of the Pennsylvania gas coal, large quantities of which are used in the furnaces at the Bessemer-steel works of Carnegie Brothers & Co. The table of analyses shows the great resemblance of these coals. The unwashed slack of that coal contains 11.60 per cent. of ash and 1.26 per cent. of sulphur, the washed slack only 6.98 per cent. of ash and 0.96 per cent. of sulphur.

"In 1870 there were two establishments in the State making coke in ovens, and these two had about thirty ovens. These were the Rockwood and Etna mines. Coke had been made in Tracy City, but up to that date only in pits on the ground.

"The great problem to be solved in the southern iron making is the production of cheap coke. It is not probable that we can ever compete in cost with Connellsville, where the mining of the coal costs only 1 cent per bushel; but, taking into consideration the higher charges for railroad transportation which the makers there have to pay, it may be possible to place our coke in a central market like Chattanooga at as low a rate as Connellsville is placed in Pittsburgh. It is evident, however, that such cheap coke must come from a field not now at all or but little developed, and there can be no doubt that the regular seams of the Upper Measures of Poplar creek, of the upper Crooked Fork, of Coal creek, and that vicinity offer greater probabilities for having coal mined at low rates than any other part of the State. If these coals can be mined at 1½ cents per bushel, in them will be found the solution of the cheap-coke problem, and at the same time the standard of quality will be reached.

"Mr. Scott, of Oakdale, says that in a series of experiments 100 bushels of the Poplar Creek coal made from 120 to 125 bushels of coke; that is, 8,000 pounds of coal made from 4,800 to 5,000 pounds of coke; and in a carefully measured month's run of the furnace, with a poor hot blast, an average of 37 tons per day was made, with 75 bushels to the ton. Maj. E. Doud, undoubtedly one of the most careful as well as successful furnace men, says that the Poplar Creek coal has no superior anywhere, and that that region must eventually be the Connellsville of the South."

The statistics of the manufacture of coke in Tennessee for the years 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Tennessee, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	6	6	8	11	*a* 13
Ovens built	656	724	861	992	1,105
Ovens building	68	84	14	10	*b* 175
Coal used, short tons	217,656	241,644	313,537	330,961	348,295
Coke produced, short tons	130,609	143,853	187,695	203,691	219,723
Total value coke at ovens	$316,607	$342,585	$472,505	$459,126	$428,870
Value coke at ovens per ton	$2.42	$2.38	$2.52	$2.25	$1.95
Yield of coal in coke, per cent	60	60	60	62	63

a One works made coke in pits.
b The construction of other ovens has been begun since January 1, 1885.

UTAH.

All attempts to manufacture coke in Utah on a commercial scale have so far proved unsuccessful, though some little coke has been made at various points in the Territory. The most systematic attempts at its manufacture have been made in the San Pete valley. Twenty coke ovens of the Coppée type were erected some years ago, and a few hundred tons of coke were made and sold to the Sandy smelters, but none has been produced since 1882. The yield of coal in coke was very low, only some 50 per cent., requiring 2 tons of coal to make 1 ton of coke. It seems to have been high in ash, and its calorific power inferior. Its cost, also, laid down at points of consumption within the Territory, was in excess of the price at which cokes from Colorado of a somewhat better quality could be furnished. It is stated that the coke produced at the coke ovens of the Pacific Coal and Coke Company, limited, above referred to, was somewhat heavier than Connellsville. Its value is given as $10 a ton at the ovens. All the coke made commercially in Utah has been manufactured in this locality. The statistics given below, therefore, are for the San Pete valley.

No analyses either of the coal or cokes of the San Pete valley have been procured from the companies working the coals, but the following analysis is taken from another source:

Analysis of San Pete coal.

	Per cent.
Water	2.05
Volatile matter	31.07
Fixed carbon	49.85
Ash	17.02
	99.99

A coke made from a coal analyzing as above, and yielding but 50 per cent. in the ovens, would be so high in ash as to have apparently but little value as a fuel for smelting purposes. It would also seem from other statements that the coal carries in the line of fracture scales of sulphate of lime, which would indicate a considerable percentage of sulphur not shown in the above analysis. Another analysis of the coal from this valley gives but 13.3 per cent. of ash, but even this percentage of ash would indicate a coke too high in ash to be of great value as a fuel.

Coke has also been made in Pleasant valley, a great coal field lying east of the San Pete valley, and it is believed that selected coals of the great coal field in Castle valley, adjoining Pleasant valley on the south, will make coke. Mr. J. Blodget Britton, of the Iron Masters' Laboratory of Philadelphia, gives the following analyses of the coals and cokes from Castle valley:

Analyses of coal and coke from Castle valley, Utah.

	Coal.	Coke.
	Per cent.	*Per cent.*
Volatile matter	40.61	2.70
Fixed carbon	48.21	94.05
Ash	1.88	3.25
	90.70	100.00

The statistics of the manufacture of coke in Utah for the years 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Utah, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	1	1	1	1	1
Ovens built (all Coppée)	20	20	20	20	20
Ovens building	0	0	0	0	0
Coal used in ovens, short tons	2,000	0	500	0	0
Coke produced, short tons	1,000	0	250	0	0
Total value of coke at ovens	$10,000	0	$2,500	0	0
Value of coke at ovens per ton	$10	0	$10	0	0
Yield of coal in coke, per cent	50	0	50	0	0

VIRGINIA.

The only coke made in Virginia during the years covered by this report was made at Pocahontas, from the well-known Flat Top coal, by the Southwest Virginia Improvement Company. Coking began here in the summer of 1883, with a plant of 200 ovens. Prior to this enterprise all attempts to manufacture coke in Virginia had been on a small scale, and the results were not at all satisfactory. These attempts were made with the coal from the Richmond coal field, which does not appear to be well adapted to the manufacture of coke. It was not until the opening of the great Flat Top coal field that a coal suitable for coking was available in Virginia.

The Flat Top coal beds belong to the lowest member of the Coal Measures, and are the equivalent of the Seral or Pottsville Conglomerate of Pennsylvania. In Professor Fontaine's examination of the measures of the lower New river, in West Virginia, they were named the Quinnimont group. This group attains its maximum thickness in the vicinity of the Flat Top area. East, west, and south and northeast they are either valueless or much inferior. It is only to the northwest, on the New river, that the beds, though thinner, retain any value, the coal still remaining excellent in quality. The Coal Measures seem to be nearly horizontal, the rise being no more than is needed for drainage.

The coal from which coke was made is known as the Nelson or Pocahontas bed, having three seams of coal, with two slate partings. The total thickness of coal is 11 feet 8 inches, in a total thickness of the bed of 12 feet 7 inches. At present the large 6-foot bench only is mined, leaving the upper 4 feet 8 inches of coal in the roof and the 1-foot bench in the floor, with the expectation of winning them both hereafter.

An analysis of a sample of the run of the mine from Mine No. 1, by Professor McCreath, is as follows:

Analysis of Flat Top, Pocahontas, Virginia, coal.

	Per cent.
Water	.684
Volatile matter	19.964
Fixed carbon	73.021
Sulphur	.656
Ash	5.675
	100.000

Samples of the lump coal would show a better analysis than this. A determination by Professor Chandler showed but 1.38 per cent. ash. No analysis of the coke has been secured. It is stated to be hard, bright, of an open cellular structure and great strength. The furnace of the Crozer Iron and Steel Company has used it exclusively since the first two months of its blast. The manager reports that he finds it equal to the Connellsville coke, and that he has no difficulty in carrying 2 pounds of ore per 1 pound of coke.

The coke is winning favor all through the South, both as a furnace and foundry coke competing with the Connellsville. It is used at most of the important foundries of Tennessee, Georgia, and Alabama, without the least complaint as to its melting power. As compared with Connellsville coke, Pocahontas coke probably contains less sulphur and perhaps a trifle less ash. In cellular structure the difference is slight, the Pocahontas being a little more dense. In size the Connellsville has the advantage. It draws in large pieces, and, being together, stands handling somewhat better. This is due to the much higher percentage of oil in Connellsville coal. While Pocahontas is strong enough for all furnace burdens, yet, as compared with Connellsville, there is a shade higher percentage of loss in handling, on account of its brittleness. On this account it is not to be expected that Pocahontas will ever be on the same footing as Connellsville for shipment to distant points, freights being equal.

The statistics of the manufacture of coke in Virginia for the years from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in Virginia, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	0	0	0	1	1
Ovens built	0	0	0	200	200
Ovens building	0	0	0	0	0
Coal used, short tons	0	0	0	39,000	99,000
Coke produced, short tons	0	0	0	25,340	63,600
Total value of coke at ovens	0	0	0	$44,345	$111,300
Value coke at ovens per ton	0	0	0	$1.75	$1.75
Yield of coal in coke, per cent	0	0	0	64½	64½

WASHINGTON.

The Tacoma Coal Company is making at its mine at Wilkeson, Pierce county, what is probably the only coke made on the Pacific coast. Mr. W. H. Fife, the vice-president of the company, states that at this mine there are several good veins of coal, the one from which the coking coal is procured being 8 feet thick. The coke is made in pits 4 feet high, inclosed on the side and ends with stone walls. The coal yields 57 per cent. of coke. The coke finds a market at the foundries in the vicinity of the works, and at Portland, Oregon. Some 400 tons have been made, which is valued at $4.50 to $5 a ton at the ovens. Mr. Fife sent samples of this coke to the *Iron Age*, which reports upon it as follows: "It seems to be a very fair quality of coke, more resembling English than Pennsylvania. Whether from inherent weakness or from the shocks it has received in transcontinental transportation in a paper box, it seems to be rather brittle, and we should scarcely expect it to hold up much of a burden in a furnace. We should also judge from its appearance that the percentage of ash runs somewhat higher than one would expect to find in strictly first-class coke. It is, however, unquestionably a practical fuel."

This coal field lies some 25 miles east of Tacoma, which is the shipping point, and extends for many miles north and south, with a width of some 12 miles. From three mines near Tacoma the coal analyzed as follows:

Analyses of Tacoma, Washington, coals.

	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Water	1.3	1.1	1.3
Volatile matter	35.0	35.1	23.7
Fixed carbon	53.9	54, 5	55.7
Ash	5 8	9.3	19.3
	96.0	100.0	100.0

The mines can be worked by drift above water level. The thickness of the veins is given as from 5 to 15 feet.

The following statistics from this works, the only one in the Territory, are for 1884, the only year in which coke has been made:

Statistics of the production of coke in Washington in 1884.

Number of establishments	1
Number of ovens built (pits used)	0
Number of ovens building	0
Coal used in the production of coke, short tons	700
Coke produced, short tons	400
Total value coke at ovens	$1,900
Value coke at ovens per ton	$4.75
Yield of coal in coke, per cent	57½

WEST VIRGINIA. (a)

The localities in which coke is made in West Virginia may for convenience be divided into three districts—the Kanawha, the New River, and the Northern. The first two are compact and continuous, and groupings that naturally suggest themselves; the third includes the ovens of Preston, Taylor, Harrison, and Marion counties, and those at Wheeling, in Ohio county.

The field of coking coals on the Kanawha river, and especially that part of it worked on its branch, the New river, including the coal of the Flat Top region, is one of the most important and valuable of the Appalachian basin. The coke made from these coals is a most excellent fuel, and though it has not as yet and may not obtain as wide a market as the Connellsville, it will not be because of its inferiority. It contains, as a rule, less ash, and is nearly if not quite as strong and vigorous as a furnace fuel. As a rule, the veins of the New river are not as thick nor as uniform in their thickness as those of Connellsville, nor as well located for economy of handling between the mine and ovens. It is, however, one of the two most important areas of first-class coking coal of the country.

The Kanawha district.—The careful examination and study of Prof. I. C. White, of the United States Geological Survey, of the coal fields of the Great Kanawha valley, during the summer of 1884, are of the utmost importance, both economically and scientifically. A summary of this report has been published in *The Virginias* for January, 1885. From this report it appears that all the coal coked in the Kanawha and New River districts of West Virginia is from the Lower Coal Measures, No. XIII. of Rogers's survey, and from the Pottsville Conglomerate, No. XII. of Rogers's classification. The correlation of the Kanawha coals No. XIII. with those of Pennsylvania is given by Professor White as follows:

Pennsylvania coals.	*Kanawha (No. XIII.) coals.*
1. Upper Freeport.	1. Lower Coalburgh.
2. Lower Freeport.	2. Coalburgh.
3. Upper Kittanning.	3. Winifrede.
4. Middle Kittanning.	4. Cedar Grove.
5. Lower Kittanning.	5. Campbell Creek.
6. Clarion.	6. Eagle.

Of these coals only the two lower numbers, 5 and 6, are made into coke in Virginia, though considerable coke is produced from Nos. 1 and 3 in Pennsylvania, and some from the others. Using the Pennsylvania nomenclature, the Lower Kittanning (Campbell Creek) is coked at Ansted, the so-called "11-foot" bed mined and coked by the Hawk's Nest Coal Company, limited, being this coal. The Clarion (Eagle) has been extensively developed at Eagle mines, and has proved a superior coking coal. The coal coked at Saint Clair works, near the Eagle, is from the

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[a] See also pages 90 to 98, and 143.

same seam. A short distance from these works, the Great Kanawha Colliery Company was building fifteen ovens at the close of 1884, beginning coking in January, 1885. Further down the river, at Coal valley, some ovens have been built, but the coal required washing to make a coke for furnace use, and no coke has been made recently. On Davis creek, still lower down, the Black Band Iron and Coal Company has made some coke in mounds for use in its furnace. The furnace was blown out in January, 1883, since which none has been made. The seam worked at the latter place is said to be the Pittsburgh, but of this there is some doubt. The coal yielded 62 per cent. of coke, with 4.98 per cent. of ash.

Regarding the coal in the Kanawha field, Professor White's conclusions have already been quoted on page 91 *et. seq.* of this report. The following analyses of the coals of this district and the coke made from them are from various sources:

Analyses of coals and cokes of the Kanawha district, West Virginia.

	Coal.				Coke.	
	Hawk's Nest, Ansted.	Coal Valley (upper part).	Coal Valley (lower part).	Davis Creek.	Great Kanawha.	Davis Creek.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	65.99	57.20	61 60	57.48	89.920	93.88
Volatile matter	32.61	38.32	35.20	38.58	1.399	1.14
Water	1.40	.18	1.32	2.24	076	....
	100.00					
Ash	2.15	4.30	1.87	1.70	8.605	4.98
		100.00	99.99	100.00	100.000	100.00
Sulphur	.74	....	.65	.45	.216	.16

Including in the Kanawha district all the ovens from Ansted down the river, all drawing their coal from No. XIII., the following are the statistics of the production of coke in the Kanawha district for the years 1880 to 1884:

Statistics of the manufacture of coke in the Kanawha district, West Virginia, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	4	4	5	5	6
Ovens built	18	18	*a* 138	147	177
Ovens building	0	0	0	0	15
Coal used, short tons	6,789	11,516	40,782	58,735	60,281
Coke produced, short tons	4,300	6,900	26,170	37,970	39,000
Total value coke at ovens	$9,890	$16,905	$62,808	$88,000	$76,070
Value coke at ovens per ton	$2.30	$2.45	$2.40	$2.32	$1.95
Yield of coal in coke, per cent	63⅓	60	64	64⅔	64⅔

a Eighty of these ovens are Coppée, the balance beehive.

The coke finds its chief market at the blast furnaces along the line of the Chesapeake and Ohio railroad and its branches, but some is sent to Chicago and other western markets. The Hawk's Nest ovens, at Ansted, were erected to supply the Victoria furnace, in Virginia, with coke. These ovens are the only ones in West Virginia not of the beehive pattern. They are Belgian or flue ovens of the Coppée type, with improvements by Soldenhof, the engineer who constructed them. They were built with the expectation of utilizing 95 per cent. of the carbon of the coal. The result has not justified the expectation. The coke, however, gives entire satisfaction in blast-furnace practice, and is reported to carry as heavy if not a heavier burden than Connellsville. The cost of repairs has been much greater than estimated, and the output per oven less than anticipated. The beehive oven, so far, gives the best results with the New River and Kanawha coals. These coals are not dry enough to require as hot an oven as the Belgian.

The New River district.—The Coal Measures just described stretch along the Kanawha from Charleston to the Gauley mountain, on the New river, a little above its junction with the Kanawha. Just beyond this, at Nuttall, the coals of the New river, the No. XII. of Rogers, the Pottsville Conglomerate of the Pennsylvania survey, begin to be utilized for coking purposes, and from this point, along the cañon of the New river, to where the lowest bed of the series goes into the air at Quinnimont, the coals of all three beds of these measures are used for coking, making a coke high in carbon, low in ash, strong and vigorous, and giving the best results as a furnace fuel. Indeed, no better coking coal is found in the whole Appalachain basin from Pennsylvania to Alabama.

Including the Flat Top field, the New River coal field is about 50 miles long from northeast to southwest, and about 30 miles wide. The productive coals of this series are three in number: (1) Nuttall; (2) Quinnimont; (3) Fire Creek. These are all excellent coking coals. Professor White's description of them has been quoted on page 97 of this volume.

The purity of the coals and their cokes can be seen from the following analyses:

Analyses of New River, West Virginia, coals.

	Nuttall.	Low Moor.	Sewell.	Fire Creek.	Quinnimont (lump).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	70.66	71.82	72.32	75.499	79.25
Volatile matter	25.35	24.43	21.38	22.425	18.65
Ash	2.10	1.34	5.27	.805	1.11
Sulphur	.53	.371	.27	.536	.46
Water	1.35	2.41	1.03	.735	.76
	99.99	100.371	100.27	100.000	100.23

Analyses of New River, West Virginia cokes.

	Nuttall.	Low Moor.	Sewell.	Fire Creek.	Quinnimont—1.	Quinnimont—2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	91.22	94.03	92.00	91.940	93.85	93.11
Volatile matter	....	.58	....	.492	....	....
Ash	7.53	3.90	6.73	6.928	5.85	5.94
Water	....	1.49	....	.102	....	....
		100.00				
Sulphur	.92	.494	.27	.538	.30	.82
	99.67		99.00	100.000	100.00	99.87

All of the ovens in this district are beehive of the ordinary pattern. The charge of coal is 3 tons, the time of coking forty-eight and seventy-two hours. The yield is about 64 per cent. as the average. In 1879, at Sewell, it was 65⅝ per cent.; at Quinnimont, for five months, 66.7 per cent.

The statistics of the manufacture of coke in the New River district from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in the New River district, West Virginia, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	6	6	6	6	8
Ovens built	468	499	518	546	547
Ovens building	40	0	0	0	12
Coal used, short tons	159,032	219,446	233,361	264,171	219,839
Coke produced, short tons	98,427	136,423	148,373	167,795	135,335
Total value coke at ovens	$239,977	$334,652	$352,415	$384,552	$274,988
Value coke at ovens per ton	$2.44	$2.45	$2.38	$2.29	$2.03
Yield of coal in coke, per cent	62	62	64	64	62

Back of the river northeast from Quinnimont, in Greenbrier county, on the Little Sewell mountain, some years ago, a 3½-foot vein of coal was coked to some extent, and the coke used in a forge near the White Sulphur Springs. It is said to have made an excellent coke. Fragments of the coke may be picked up still. They show a firm, brilliant, compact coke.

The northern district.—In this district are included the ovens in a group of counties lying along the Baltimore and Ohio railroad on the headwaters of the Monongahela river—Preston, Taylor, Harrison, and Marion—and those of Ohio county, in the northern part of the "Pan Handle." The coke made at Wheeling, in Ohio county, is made in small amounts, to supply a small local demand from glass works.

As yet the coke industry in this part of the State has not assumed the importance that it has on the New river, but it is making rapid advances. In the census year there were in this district but six works making coke, four in Preston county and one each in Marion and Ohio counties. At these works there were 169 ovens. At the close of 1884 there were thirteen establishments, with 281 ovens. In addition, quite a number of ovens are contemplated and others under construction. The coke is a good furnace fuel, and while not as pure as that made from the coals of No. XII., it is very nearly as valuable for furnace purposes as the New River, and the coal is mined and coke made under more favorable circumstances. Speaking of the coal from the Pittsburgh bed of this locality, Professor White says "it cokes well," and of the coke from the Upper Freeport bed he states that "it is shipped to Chicago, where it finds a ready market and competes successfully with Connellsville coke."

The coal used in the manufacture of coke in this district, with the exception of two works, is from the Pittsburgh bed. As mined by the Newburg-Orrel Coal Company, in Preston county, this seam is from 10 to 11 feet thick. Only 9 to 9½ feet are worked, however, the rest being left to support the roof. At the Tyrconnel mines of this same company, in Taylor county, it is 9 feet; at Clarksburg, Harrison county, 8 feet 10 inches; and at Wilsonburg, in the same county, 7 feet 6 inches. The coke made from this coal is reported by Maury to be compact and handsome, but liable in some localities to contain an excess of sulphur. This is not true of all the cokes made in this district.

The following are analyses of two of the coals of the Pittsburgh bed in this district:

Analyses of coals of the Pittsburgh bed in West Virginia.

	Marion county.	Harrison county.
	Per cent.	*Per cent.*
Fixed carbon	67.50	60.00
Volatile matter	32.50	....
	100.00	
Ash	2.10	6.70
Sulphur	.95	....

The only analysis of coke obtained is the following, from Preston county:

	Per cent.
Fixed carbon	89.30
Volatile matter	.54
Ash	9.30
Sulphur	.70
Moisture	.16
	100.00

At Austen, Preston county, the Upper Freeport seam, which is here from 5 to 5½ feet thick, is coked. The coal is too soft to bear handling or transportation. Professor Lesley reports that this coal makes "a clear, even, silvery coke, sufficiently hard to bear the heaviest burden of the blast furnace." Regarding it Professor White says: "Since this coal is successfully worked at the Irondale furnace, on Three forks, as at Austen, there would seem to be good reason for believing that this great basin, 8 to 12 miles wide, stretching across Preston county from the Pennsylvania line to the Baltimore and Ohio railroad, and all underlaid by this coal, will yet furnish much valuable coking coal."

The following are analyses of this coal and coke as mined and coked at Austen:

Analyses of Austen, West Virginia, coal and coke.

	Coal.	Coke.	
		48 hours.	72 hours.
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	66.28	90.56	87.98
Volatile matter	31.12		
Ash	2.48	9.19	11.57
Water	.12	.25	.45
	100.00	100.00	100.00
Sulphur	.64	.19	.21

The yield of coal in coke was 66 per cent.

It is evident that the coke could not have been made of the coal of which an analysis is given. Probably the coal analysis is selected lump, the coke being from the run of the mine or slack.

The statistics of the production of coke in the northern district for the years from 1880 to 1884 are as follows:

Statistics of the manufacture of coke in the northern district, West Virginia, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	8	9	11	13	13
Ovens built	145	172	222	269	281
Ovens building	0	0	0	0	100
Coal used, short tons	64,937	73,863	92,510	88,253	78,468
Coke produced, short tons	36,028	43,803	55,855	51,754	49,139
Total value coke at ovens	$68,930	$78,014	$105,214	$90,848	$74,894
Value coke at ovens per ton	$1.91	$1.78	$1.88	$1.76	$1.52
Yield of coal in coke, per cent	55	59	60	59	63

The Potomac coal field.—Though little or no coke has been made from the coal in what is known as the Piedmont or Potomac coal basin, it may be well to refer to it, as it promises in the near future to be of some importance as a source of supply for coking coal. The West Virginia Central and Pittsburgh railway, which starts from Piedmont, on the Baltimore and Ohio railway, runs southwesterly east of the main range of the Alleghanies, through Mineral, Grant, and Tucker counties. Mr. Owen Riordan, formerly inspector of mines in Maryland, reports that he opened in the upper or southwestern portion of this Potomac coal field a bed of gas coal 6 feet thick, one of 4 feet 6 inches thick, a bed of good coking coal 4 feet thick, and several beds of smithing and steam coals, one of them 9 feet, all free of slate and other impurities.

The seam of the chief value is what is known as the "Big vein," which at Elk Garden, Mineral county, is 14 feet thick. Some excellent coke has been made from this seam. Some years ago the old Hampshire Company tested it in pits, and found it made hard, silvery coke, sufficient to stand the heaviest furnace burden. The following are analyses of coke made from the coals of this basin:

Analyses of cokes of the Piedmont or Potomac, West Virginia, coal basin.

	Upper Potomac 5-foot bed.				Elk Garden 14-foot bed.	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	90. 90	87. 84	89. 82	89. 05	88. 65	89. 61
Volatile matter	. 82	1. 36	. 50	1. 17	. 70	. 86
Moisture	. 23	. 59	. 54	. 18	. 56	. 30
Sulphur	1.26	. 94	. 94	. 14	. 69	. 94
Ash	6. 77	9. 25	8. 18	9. 46	9. 40	8. 24
	99. 98	99. 98	99. 98	100. 00	100. 00	99. 95

Total coke production in West Virginia.—Consolidating the statistics of the different districts of West Virginia given above, the following are the statistics of the production of coke in West Virginia from 1880 to 1884:

Statistics of the manufacture of coke in West Virginia, 1880 *to* 1884.

	1880.	1881.	1882.	1883.	1884.
Number of establishments	18	19	22	24	27
Ovens built	631	689	878	962	1, 005
Ovens building	40	0	0	0	127
Coal used, short tons	230, 758	304, 823	366, 653	411, 159	358, 588
Coke produced, short tons	138, 755	187, 126	230, 398	257, 519	223, 472
Total value coke at ovens	$318, 797	$429, 571	$520, 437	$563, 490	$425, 952
Value coke at ovens per ton	$2. 30	$2. 30	$2. 26	$2. 19	$1. 91
Yield of coal in coke, per cent	60	61	63	63	62

PETROLEUM.

By S. H. Stowell.

THE OIL FIELDS OF THE UNITED STATES.

Pennsylvania and New York.—A recent publication of the second geological survey of Pennsylvania is a map of the oil regions of western Pennsylvania and southwestern New York, on which are outlined with great distinctness all the areas producing petroleum discovered prior to July, 1884. From this map a very clear idea can be obtained of the extent of the oil regions in these States.

Commencing at the north in Allegany county, in New York, we have the main field, the Richburg or Allegany field, of very irregular shape, but having an average length of 20 miles. Outlying this district in the same county are three smaller fields, of which one, about a mile from the town of Niles and bearing its name, is the farthest north of any development. The Wirt field, midway between Niles and the main field, is larger, but produces more gas than oil. The Bradford oil district, the next in order, is generally spoken of as in the Pennsylvania district. The main field, however, extends at least 5 miles into the State of New York, and an outlying basin of oil rocks, which properly belongs to the Bradford basin, is contained for the greater part in Carrollton township, in Cattaraugus county, New York.

In Warren and Forest counties, Pennsylvania—the middle oil field—there is no large continuous deposit. The most important are the Clarendon, the Cooper and Sheffield, and the Balltown districts. Of these the former is the largest and perhaps the most important. It covers a large part of Mead township, Warren county, and is elliptical in shape. The wells are of fair size and are usually long lived. The Cooper and Sheffield district lies partly in Warren county and partly in Forest, is smaller than the Clarendon district, and is "spotted" territory; that is, the oil-producing rock seems to underlie the districts in spots. The Balltown field is perhaps 10 miles long by 1 wide, and lies along Tionesta creek, in Forest county, in the vicinity of Balltown. Quite large wells have been found here. About midway between the Balltown field and the Clarendon field lies the once famous Cherry Grove district, which until the development of the Thorn Creek field, Butler county, in the early part of 1884, had the distinction of having had within its limits the largest wells known to the trade. The district is of very little importance at present.

The lower field begins with a few deposits in the southwestern corner of Warren and the western end of Forest counties, and is considered to terminate in Butler county, the deposits being chiefly contained in Venango, Clarion, and Butler counties. Many, in fact the larger proportion, of the deposits in this field are of but trifling importance at present. Most of them bear names which twenty-five years ago were famous the country over. Among these may be named the small districts of Enterprise, Fagundus, Pithole, Cashup, Walnut Bend, and others. From these, however, the glory has departed and many of them produce no oil whatever at present. The largest district in Venango county is the Oil Creek field, which follows generally the line of direction of the stream from which it takes its name, at the north diverging into the northeastern corner of the county. At various points all over the county are smaller deposits, many of which, as has been said, produce no oil at present. Of the remainder a few produce small quantities of green and black oil; quite a number produce "heavy" or lubricating oil. The production of this county is insignificant as compared with those previously mentioned.

Passing south the long and measurably continuous belt of Clarion and Butler counties is reached. This is a district of later date than the Venango county field, having been developed in 1869 and 1870, during the decline of the Oil Creek deposits. This field is crossed near its southern extremity by the Butler "cross belt," in which good wells have been drilled, drawing their oil from the fourth sand. This cross belt extends east in Armstrong county, and several small pools are also found in that county.

About 10 miles east of the southern extremity of the Clarion-Butler field lies the Bald Ridge pool on Thorn creek, now better known as the Thorn Creek field. Here most important wells have been developed.

There are a few other isolated deposits in the western and southwestern parts of the State not generally considered in connection with the fields just described. Of these the most considerable is the field on the Ohio river in Beaver county, which has about the dimensions of the Clarendon field in Warren county, but by no means the importance as to production. The Slippery Rock field along Slippery Rock creek in Lawrence county, the Pleasant Unity field in Westmoreland county, and the small deposits in Green county should also be mentioned. They possess, however, but little commercial importance.

Ohio.—Of the several localities in which petroleum has been found in this State, the only one of any considerable commercial importance is the Macksburg field, about 25 miles north of Zanesville. Operations have been in progress here for two or three years, but attracted but little attention until the spring of 1884, when several very fair wells were bored, and the production of the district rose, one well making over 100 barrels a day. For a time the field attracted a great deal of attention, even influencing prices on the Pennsylvania oil exchanges, but the excitement soon subsided. There are at present quite a number of producing wells in the district, but no important developments have recently been made.

At Mecca, Ohio, oil is obtained by tunneling. A recent find of oil is reported at Findlay, Hancock county.

Kentucky.—In several localities in this State petroleum has been found. Perhaps the best known district is situated on a tract of 20,000 acres of land, known as the Marshall tract, just on the Tennessee line. Here two shallow wells have for some years been producing about 3 barrels each per day. Recent reports state that two large companies have been formed, mainly of Pennsylvania oil men, to develop this district.

Along the banks of the Big Sandy river, in Martin county, several oil springs exist, and the indications here are favorable for the production of lubricating oil. Steps have been taken to develop this district also.

Another field was recently discovered in Montgomery county by the sinking of a shallow well by a Virginia capitalist. A report on the oil found here was made by Dr. H. Froehling, of Richmond, to *The Virginias*, from which it appears that the oil is a petroleum of 21° specific gravity, and will doubtless make a fine grade of lubricating oil.

West Virginia.—The oil district in West Virginia, in the vicinity of Volcano, still keeps up a small production. The wells here are very deep and yield lubricating oil.

Colorado.—Petroleum has been found in many localities in this State, the chief deposits being located in Fremont county. Here, at as early a date as 1865, small wells were sunk on Oil creek, a few miles northeast of Cañon City, the oil from which was transported by wagon to Denver and used for illuminating purposes. The industry, however, soon died out, and no further steps toward the development of the State's oil resources were taken until 1882. In this year the Land Investment Coal and Oil Mining Company was formed, and purchased about 14,000 acres in the vicinity of Cañon City. This company has bored two wells, one of which was the first bored in the district. Both are down about 1,250 feet, and produce together about 3 barrels per day, the petroleum being an excellent quality of lubricating oil.

About 11 miles southwest of Cañon City the Arkansas Valley Oil Company has commenced operations. This company drilled a well in 1883, which is now producing about 1 barrel per day. The successful striking of oil in this well induced the company to take steps toward a more extensive development of its property, and a contract for drilling ten wells was let, the first of which struck oil in November, 1884. This well is the best yet drilled, producing steadily 5 barrels per day. These wells are near the eastern edge of the oil basin. The oil produced here is lubricating oil of 30° gravity.

These two companies are the only ones at present engaged in producing petroleum. About 5 miles northeast of Cañon City is the "dry" hole of the Cañon City Oil Company. This well is a "dry" well in oil parlance alone, the trouble which interfered with its success as an oil producer being a superabundance of water. This could not be satisfactorily cased off, and the well was abandoned at a depth of 1,800 feet. Another unsuccessful well is that drilled by Mr. Lyman Robinson, about 7 miles from Cañon City, which was abandoned at a depth of 1,700 feet, no oil in paying quantities having been reached.

In various other parts of the State oil in greater or less quantities has been found. Oil springs and other indications seem to point to the existence of petroleum in paying quantities, in the vicinity of Walsenburg, in Huerfano county, and a local company has been formed to operate there. There are also indications of oil along Grand river, and a promising field seems to exist in that portion of the State. Oil springs also exist near Morrison, on a tributary of Bear river, and in numerous other localities.

Wyoming.—For many years petroleum has been known to exist in Wyoming. The oil area has not yet been determined, either by prospecting or geological investigation. Enough has been discovered, however, to establish the existence of several important districts. Of these five have been located and their boundaries in part defined, namely, the Shoshone, Beaver, Rattlesnake, Seminoe, and Powder River basins. Unlike the better-known oil fields of Pennsylvania and other Eastern States, no deep borings are necessary in order to find the oil. It is invariably near the surface, and in many cases appears in the form of "oil springs," spontaneously escaping to the surface. Over much of the oil territory of Wyoming the oil which has escaped has hardened and formed a crust, through which, immediately upon penetration, the petroleum oozes. These circumstances render it much easier to get at the oil than in the eastern States and elsewhere, where deep boring is required.

The Shoshone basin is situated 78 miles north of Point of Rocks station, on the Union Pacific railroad, and has an area of about 60 acres. Over all this area oil spontaneously escapes at places. Much of this district is covered by a crust of hardened oil from 1½ to 3 feet thick, which is overlaid by several feet of alluvium. The crust being penetrated, oil at once rises to the surface. It is intensely black in color, and has been successfully used as a lubricant. Dr. George B. Graff, of Omaha, as early as 1876 began to make efforts tending to the development of this field, and at length formed a company which began to drill a well last winter. Oil, of course, collected in the hole as soon as it was a few feet in depth; but drilling was continued, and on February 13, 1885, the promoters of the venture were rewarded by the striking, at a depth of 109 feet, of a large deposit of oil, the well producing, at last accounts, 84 barrels a day, the yield being on the increase. The oil is yellowish brown, and its specific gravity is about 20°. It will be chiefly valuable as a lubricant, but will yield 40 per cent. of illuminating oil.

The Beaver oil basin is situated 35 miles directly east of the Shoshone, and in many respects differs from it. Much gas constantly escapes in the vicinity of the oil deposits. No information is at hand with respect to any developments of this region, if any have been made.

The Rattlesnake basin is 35 miles east of the Beaver basin. The oil here is chiefly found along the cañons of several creeks which have cut through the hills. The line along which the oil "shows" is about 4 miles long. The oil resembles that of the other two deposits. In this basin the Central Association of Wyoming is now boring a well, and the Rawlins Petroleum Association, which owns a large tract of land in the district, will also soon begin operations.

The Seminoe basin lies between 25 and 30 miles east of the Rattlesnake basin. The surface indications do not extend over so wide an area as in the other basins, but it seems probable that there is here a very large deposit of oil. The Seminoe oil resembles more nearly kerosene.

At the head of Powder river important oil springs are found. In this district oil is often secured by sinking pits, into which the oil oozes and is collected. The Central Association of Wyoming contemplates developing this district also, and is about to put down a well. The Denver Oil Company of Colorado has purchased territory in this district and has a well under way.

Oil has been found in many other parts of Wyoming, notably at Jenny's Stockade, on the eastern side of the Territory, in Uintah county, and on the line between Wyoming and Dakota. Developments are now being energetically pushed, and the fluid seems destined to become one of the Territory's most important commercial products.

California.—Petroleum was first discovered in California not long after the boring of the first well in Pennsylvania in 1859. The excitement attending the discovery of the fluid in the East spread over the country, and induced many in various portions of the United States to explore for indications, which were soon found in abundance in California. As early as 1865 there were seventy oil corporations organized in this State, with a nominal capital of $45,000,000, and forty or fifty wells were started, chiefly in Humboldt county. These were trivial affairs, the deepest having a depth of only 400 feet. They were all "pumpers," not one being a flowing well. The product for the year was about 1,200 barrels. The industry soon declined, and, while operations were continued until 1867, during which year one well was bored to a depth of 1,300 feet, practically died out after that date, and was not renewed until 1875. In this year prospectors came from Pennsylvania and sank two small wells, which were successful, producing from 15 to 20 barrels daily. As a result of this venture the Pacific Coast Oil Company, at present the leading oil company on the coast, was organized in 1879. Since that time it has bored twenty-four wells in Los Angeles and Ventura counties, of which twenty are now producing. The wells in the San Fernando district, in Los Angeles county, furnish the larger part of the oil produced by this company. One of these wells has been producing for seven years, and is now yielding from 25 to 30 barrels daily. Its largest yield was 80 barrels in one day, this being obtained during a voluntary flow. The largest daily yield of any of these wells, at present, is 110 barrels. They produce a total of 625 barrels daily. The oil is said to be the best found on the coast, a large part of it being manufactured into high-grade illuminating oils.

The wells of the company in Ventura county are all shallow, some petroleum being produced by tunneling. The oil is dark and heavy, and is principally used for fuel. The total production of all the wells of the company is 700 barrels daily, an average of 35 barrels to each well.

The Pacific Coast Oil Company is also producing about 12 barrels daily from a deposit of petroleum in the Santa Cruz mountains, Santa Clara county, about 18 miles back of San José. The company is making preparations to develop other deposits, and will doubtless soon largely increase the production.

The only other company at present actively engaged in producing petroleum in California, according to the San Francisco *Bulletin*, from which much of this information is derived, is the Trinitar Oil Company, which is producing from 10 to 12 barrels daily from a deposit near Pescadero, in San Mateo county. The grade of this oil is good.

Petroleum is known to exist in many counties of this State. Besides those mentioned, there are Santa Barbara, San Luis Obispo, and Kern counties. According to a survey of the oil field of these counties made in 1877, the belt covered by the deposits is 60 miles long and averages 8 miles in width. It has been estimated that this belt does not contain over one-half of the oil deposits of California.

The following figures, estimated in part, give the petroleum production of California since 1879:

Production of petroleum in California since 1879.

Years.	Barrels.	Years.	Barrels.
1879	13,543	1882	128,636
1880	40,552	1883	142,857
1881	99,862	1884	262,000

California has, however, depended largely in the past upon importations of petroleum for her supply. Before the building of the railways across the continent all the petroleum imported came in ships by way of Cape Horn. Of late much of the oil imported comes by rail, in tank cars and barrels, but the ocean route has not been abandoned, nearly every vessel from New York bringing a consignment. The following figures show the imports of crude oil from the East from 1864 to the close of 1883, as nearly as can be ascertained from the best sources at hand:

Receipts of petroleum at San Francisco since 1864.

Years.	Barrels.	Cases.	Years.	Barrels.	Cases.
1864	50	94, 635	1875	2, 125	155, 398
1865	....	55, 231	1876	2, 942	350, 658
1866	129	126, 835	1877	1, 736	314, 005
1867	59	134, 252	1878	2, 271	310, 254
1868	....	125, 690	1879	11, 570	233, 167
1869	....	136, 281	1880	1, 844	100, 124
1870	....	62, 809	1881	2, 547	71, 368
1871	....	221, 111	1882	884	141, 804
1872	2, 719	209, 289	1883	3, 000	292, 185
1873	1, 599	154, 897			
1874	2, 207	315, 131	Total	35, 682	3, 605, 124

A case contains two 10-gallon cans of oil. The total imports for the period covered by the figures have thus been 1,752,408 barrels of 42 gallons each.

Transportation facilities for the moving of oil in the State are yet in their infancy. The Pacific Coast Oil Company has, however, constructed two systems of pipe lines, one carrying the oil from the Los Angeles county wells to the Southern Pacific railroad, on which the transportation is completed by tank cars, and the other carrying the oil to San Buenaventura, one of the landings of the Pacific Coast Steamship Company, from which point it will be transported to San Francisco in tanks on board of vessels.

The uses of petroleum in California, as in the East, are various. The Pacific Coast Oil Company has built extensive refineries at Alameda Point, at which most of its product is manufactured. It is estimated that the company at present supplies one-third of all the refined petroleum used in California. Much of the oil consumed in the State is, of course, illuminating and lubricating oil, native oil being used by many railroads for the latter purpose. Gas making also utilizes considerable oil. The Central Gaslight Company, of San Francisco, uses 60 barrels of crude oil daily, and the Oakland Gaslight and Heat Company, as well as many other interior gas companies, use petroleum in a limited way in the manufacture of gas, in connection with coal.

Petroleum is also used to some extent as fuel in this State. Besides a limited use of it in oil stoves, at least 100 barrels are used daily in the southern counties in the generation of steam. It is used in this way to run flour mills, quartz mills, and various other manufactories. The reduction works at Daggett, on the Southern Pacific railroad, have been run in this way. It is also stated that the California Sugar Refinery, which uses 70 tons of coal daily, contemplates experimenting with petroleum as fuel.

Other States.—In Missouri, Texas, Tennessee, and other States petroleum exists, but developments, if any, have attracted little attention and are of little commercial importance.

PRODUCTION STATISTICS.

Total production of crude petroleum in the Pennsylvania and New York oil fields for the years 1871–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1871	418, 407	372, 568	400, 334	385, 980	408, 797	410, 340	456, 475	462, 582	461, 940	485, 243	464, 610	477, 958	5, 205, 234
1872	583, 575	462, 985	461, 590	462, 090	537, 106	491, 130	517, 762	549, 909	500, 430	442, 432	638, 610	645, 575	6, 293, 194
1873	632, 617	608, 300	665, 291	641, 520	776, 364	793, 470	867, 473	936, 138	954, 270	942, 493	991, 470	1, 084, 380	9, 844, 744
1874	1, 167, 243	835, 492	883, 438	778, 740	895, 745	921, 750	1, 033, 447	931, 519	840, 630	919, 739	861, 060	858, 142	10, 926, 945
1875	852, 159	719, 824	789, 539	675, 060	696, 508	696, 210	788, 361	718, 766	698, 940	731, 073	700, 200	720, 874	8, 787, 506
1876	712, 225	668, 885	718, 177	701, 490	735, 351	723, 600	763, 623	782, 223	780, 600	809, 162	786, 480	787, 090	8, 968, 906
1877	842, 890	873, 216	901, 697	972, 810	1, 127, 594	1, 130, 790	1, 189, 005	1, 273, 759	1, 214, 910	1, 269, 326	1, 173, 420	1, 256, 058	13, 135, 475
1878	1, 263, 296	1, 094, 856	1, 208, 380	1, 195, 890	1, 264, 862	1, 217, 250	1, 283, 865	1, 341, 928	1, 315, 710	1, 369, 797	1, 348, 950	1, 318, 678	15, 163, 462
1879	1, 369, 921	1, 261, 935	1, 499, 315	1, 530, 450	1, 644, 922	1, 675, 650	1, 637, 767	1, 892, 302	1, 856, 700	1, 836, 378	1, 710, 480	1, 769, 356	19, 785, 176
1880	1, 904, 113	1, 870, 008	2, 015, 992	2, 015, 700	2, 228, 931	2, 158, 440	2, 248, 430	2, 341, 027	2, 346, 300	2, 385, 636	2, 274, 420	2, 238, 634	26, 027, 631
1881	2, 244, 090	1, 913, 128	2, 274, 532	2, 205, 780	2, 393, 293	2, 377, 860	2, 372, 678	2, 331, 727	2, 193, 420	2, 323, 171	2, 266, 830	2, 480, 000	27, 376, 509
1882	2, 353, 551	2, 131, 332	2, 482, 170	2, 402, 790	2, 486, 572	2, 825, 940	3, 258, 162	3, 104, 495	2, 620, 380	2, 297, 658	2, 192, 940	1, 897, 510	30, 053, 500
1883	1, 948, 319	1, 756, 188	1, 830, 674	1, 816. 530	1, 962, 052	1, 977, 900	2, 020, 394	1, 868, 277	1, 913, 370	2, 076, 659	1, 958, 340	1, 988, 526	23, 117, 229
1884	1, 825, 838	1, 880, 650	2, 052, 262	2, 065, 860	2, 232, 403	1, 862, 190	2, 059, 950	2, 099, 165	1, 948, 260	1, 961, 866	1, 811, 700	1, 822, 614	23, 622, 758

Shipments of crude petroleum, and refined petroleum reduced to crude equivalent, out of the Pennsylvania and New York oil fields for the years 1871–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1871	437, 691	347, 718	383, 890	389, 147	587, 375	501, 754	541, 137	528, 134	551, 075	505, 071	480, 977	410, 822	5, 664, 791
1872	476, 966	407, 606	276, 220	428, 512	510, 417	529, 228	591, 238	621, 954	541, 607	607, 468	477, 945	430, 786	5, 899, 947
1873	573, 124	527, 440	668, 374	708, 191	768, 176	696, 414	814, 449	864, 768	952, 955	1, 010, 852	959, 589	955, 443	9, 499, 775
1874	843, 663	501, 220	518, 246	803, 409	899, 027	815, 413	940, 281	793, 865	1, 014, 570	543, 341	546, 117	602, 348	8, 821, 500
1875	453, 095	327, 776	693, 918	729, 581	681, 679	745, 986	904, 537	882, 089	1, 109, 392	871, 917	671, 066	871, 902	8, 942, 938
1876	677, 289	519, 193	623, 762	603, 037	646, 150	921, 862	1, 228, 539	1, 203, 402	1, 154, 549	524, 190	871, 496	1, 190, 983	10, 164, 452
1877	743, 461	484, 904	913, 919	903, 526	1, 234, 324	1, 391, 124	1, 096, 951	1, 425, 943	1, 563, 797	1, 268, 971	1, 205, 634	600, 019	12, 832, 573
1878	775, 791	774, 234	741, 512	846, 632	960, 894	1, 135, 119	1, 330, 454	1, 655, 651	1, 434, 225	1, 747, 390	1, 281, 410	992, 688	13, 676, 000
1879	663, 998	702, 729	973, 879	1, 136, 188	1, 331, 469	1, 369, 314	1, 625, 035	1, 808, 239	1, 627, 120	1, 662, 269	1, 453, 645	1, 532, 585	15, 886, 470
1880	1, 650, 409	1, 395, 151	1, 613, 371	842, 268	1, 095, 259	975, 083	1, 231, 611	1, 394, 129	1, 252, 635	1, 665, 933	1, 226, 030	1, 335, 613	15, 677, 492
1881	1, 061, 617	915, 028	1, 276, 746	1, 348, 398	1, 563, 436	1, 729, 697	1, 925, 532	2, 214, 877	2, 131, 950	2, 080, 467	2, 066, 906	1, 969, 581	20, 284, 235
1882	1, 657, 067	1, 787, 909	1, 718, 956	1, 678, 134	1, 827, 356	2, 172, 685	2, 402, 970	2, 047, 545	1, 992, 171	2, 089, 428	1, 404, 640	1, 121, 453	21, 900, 314
1883	1, 357, 815	1, 250, 824	1, 641, 899	1, 908, 379	1, 995, 634	1, 747, 789	1, 634, 407	2, 086, 478	2, 325, 574	2, 215, 421	2, 065, 602	1, 749, 547	21, 979, 369
1884	1, 686, 961	1, 723, 261	1, 873, 890	1, 643, 336	1, 899, 329	1, 827, 553	1, 740, 021	2, 000, 371	2, 292, 087	2, 510, 283	2, 078, 261	2, 382, 244	23, 657, 597

Number of drilling wells in the Pennsylvania and New York oil fields at the close of each month for the years 1871–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly averages.
1871	140	173	240	279	356	303	329	330	439	486	477	394	329
1872	363	369	313	302	386	391	359	392	301	311	354	318	347
1873	361	349	227	177	228	395	340	267	197	163	137	60	242
1874	37	55	99	213	225	210	180	128	107	82	57	54	121
1875	40	40	45	64	127	162	118	96	132	170	179	168	112
1876	142	151	230	267	307	340	353	374	511	565	618	493	363
1877	457	463	395	448	512	395	365	417	535	573	565	426	463
1878	334	326	379	409	376	266	188	185	240	282	297	218	292
1879	265	323	406	468	460	384	329	258	270	313	372	440	357
1880	540	535	577	580	460	440	452	515	491	469	475	408	495
1881	383	420	437	446	470	408	379	352	388	445	475	468	423
1882	422	438	408	405	381	226	240	194	177	184	154	138	276
1883	126	151	205	199	216	228	262	315	314	341	301	263	243
1884	270	273	260	284	244	123	123	91	79	100	86	78	168

Number of drilling wells completed in the Pennsylvania and New York oil fields each month for the years 1872–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1872	37	120	89	121	135	84	128	118	82	100	64	105	1, 183
1873	93	94	100	105	102	130	114	120	106	101	100	98	1, 263
1874	102	104	110	113	109	101	121	107	104	120	106	120	1, 317
1875	190	187	195	186	172	190	200	210	201	220	217	230	2, 398
1876	240	231	242	200	202	261	248	270	209	273	272	272	2, 920
1877	281	241	291	269	320	403	317	255	322	467	391	382	3, 939
1878	274	226	211	409	470	269	203	186	174	229	248	165	3, 064
1879	136	132	238	270	402	330	327	288	210	232	227	261	3, 048
1880	320	230	367	500	426	310	338	368	356	364	336	302	4, 217
1881	222	220	271	316	406	374	336	332	312	322	363	406	3, 880
1882	347	340	385	432	469	340	185	253	164	117	150	122	3, 304
1883	125	126	142	209	231	228	261	309	321	321	302	272	2, 847
1884	229	227	256	298	311	244	268	145	89	59	73	66	2, 265

Number of producing wells in the Pennsylvania and New York oil fields at the close of each month for the years 1872–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly averages.
1872	3,892	3,936	3,943	3,967	4,085	4,144	4,245	4,423	4,475	4,475	4,529	4,553	4,205
1873	4,485	4,490	4,411	4,265	4,317	4,400	4,420	4,163	3,940	3,654	3,413	3,358	4,109
1874	3,311	3,235	3,308	3,301	3,266	3,298	3,293	3,287	3,254	3,270	3,220	3,270	3,276
1875	3,132	3,112	3,060	3,052	3,080	3,084	3,067	3,088	3,112	3,125	3,174	3,078	3,098
1876	3,314	3,638	3,670	3,772	3,930	4,527	4,774	6,047	5,285	5,552	5,809	6,000	4,694
1877	6,283	6,441	6,666	6,846	7,037	7,352	7,564	7,684	7,872	8,061	8,323	8,458	7,383
1878	8,616	8,725	8,848	9,071	9,400	9,605	9,776	9,884	10,012	10,188	10,276	10,337	9,561
1879	10,482	10,582	10,692	10,782	11,045	11,223	11,461	11,585	11,760	11,860	11,960	11,960	11,283
1880	12,000	12,072	12,222	12,572	12,972	13,172	13,275	13,500	13,825	14,100	14,400	14,700	13,234
1881	14,900	15,050	15,500	15,769	16,150	16,700	17,000	17,250	17,562	17,799	18,040	18,300	16,668
1882	18,400	18,600	18,850	19,150	19,350	19,500	19,570	19,600	19,600	19,000	18,700	18,000	19,027
1883	17,600	17,300	17,250	17,100	17,100	17,050	17,100	17,100	17,300	19,100	20,406	20,606	17,918
1884	20,756	20,930	21,000	21,242	21,494	21,658	21,844	21,916	21,900	21,859	21,859	21,909	21,531

Average daily production of crude petroleum in the Pennsylvania and New York oil fields each month for the years 1872–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly averages.
1872	18,825	15,965	14,890	15,403	17,326	16,371	16,702	17,739	16,681	4,272	21,287	20,825	17,194
1873	20,407	21,725	21,461	21,384	25,044	26,449	27,983	30,198	31,809	30,403	33,049	34,980	27,106
1874	37,653	29,839	28,598	25,958	28,895	30,725	33,337	30,049	28,021	29,669	28,702	27,682	29,937
1875	27,489	25,708	25,469	22,502	22,468	23,207	25,431	23,186	23,298	23,583	23,340	23,254	24,075
1876	22,975	23,065	23,167	23,383	23,721	24,120	24,633	25,233	26,020	26,102	26,216	25,390	24,505
1877	27,190	27,979	29,087	32,427	36,374	37,693	38,335	41,089	40,497	40,946	39,114	40,518	35,988
1878	38,816	39,102	38,980	39,863	40,802	40,575	41,415	43,288	43,857	44,187	44,965	42,538	41,544
1879	44,191	43,515	48,365	51,015	53,062	55,855	56,057	61,042	61,890	59,238	57,016	57,076	54,206
1880	61,423	64,552	65,032	67,190	71,901	71,948	72,530	75,517	78,210	76,956	75,814	72,214	71,114
1881	72,390	68,326	73,372	73,526	77,203	79,262	76,538	75,217	73,114	74,941	75,561	80,000	75,004
1882	75,921	76,119	80,070	80,093	80,212	94,198	105,102	100,145	87,346	74,118	73,098	61,210	82,338
1883	62,849	62,721	59,054	60,551	63,292	65,930	65,174	60,627	63,779	66,989	65,278	64,146	63,335
1884	58,898	64,850	66,202	68,862	72,013	62,073	66,450	67,715	64,942	63,286	60,390	58,794	64,544

[Yearly average is total production ÷ number of days in year, *not* average of monthly averages.]

Total stocks of crude petroleum in the Pennsylvania and New York oil fields for the years 1871–'84, by years and months.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Averages.
1871	537, 751	587, 021	642, 000	771, 000	605, 000	554, 000	511, 220	530, 146	541, 300	495, 102	502, 960	532, 000	567, 458
1872	532, 971	579, 793	662, 497	877, 832	950, 803	1, 010, 302	990, 229	997, 166	951, 410	914, 423	886, 909	1, 084, 423	869, 896
1873	1, 183, 728	1, 265, 373	1, 244, 657	1, 178, 643	1, 192, 541	1, 324, 493	1, 433, 620	1, 513, 890	1, 521, 185	1, 452, 777	1, 493, 875	1, 625, 157	1, 369, 191
1874	1, 948, 919	2, 283, 032	2, 648, 210	2, 623, 534	2, 594, 286	2, 701, 625	2, 279, 479	2, 932, 444	2, 758, 504	3, 134, 902	3, 449, 845	3, 705, 639	2, 755, 035
1875	4, 011, 703	4, 546, 188	4, 592, 364	4, 537, 843	4, 552, 672	4, 502, 896	4, 386, 720	4, 223, 397	3, 812, 945	3, 672, 101	3, 701, 235	3, 550, 207	4, 174, 189
1876	3, 585, 143	3, 734, 835	3, 829, 250	3, 900, 703	3, 989, 904	3, 791, 642	3, 326, 726	3, 304, 405	2, 930, 456	3, 040, 108	2, 955, 092	2, 551, 199	3, 411, 622
1877	2, 604, 128	2, 860, 636	3, 210, 454	3, 279, 731	3, 173, 008	2, 912, 674	3, 004, 728	2, 852, 544	2, 503, 657	2, 504, 012	2, 471, 798	3, 127, 837	2, 875, 434
1878	3, 555, 342	3, 875, 964	4, 342, 832	4, 692, 090	4, 996, 058	5, 078, 189	5, 031, 600	4, 717, 877	4, 599, 362	4, 221, 769	4, 289, 309	4, 615, 299	4, 501, 308
1879	5, 321, 222	5, 813, 663	6, 318, 099	6, 689, 111	6, 980, 064	7, 263, 150	7, 353, 382	7, 114, 195	7, 620, 525	7, 794, 634	8, 051, 469	8, 470, 490	7, 065, 834
1880	8, 724, 194	9, 004, 062	9, 606, 683	10, 780, 153	11, 916, 577	13, 099, 934	14, 116, 753	15, 063, 651	16, 157, 316	16, 877, 019	18, 025, 409	18, 928, 430	13, 541, 682
1881	20, 110, 903	21, 108, 003	22, 105, 789	22, 963, 171	23, 793, 028	24, 441, 191	24, 888, 337	25, 005, 187	25, 066, 657	25, 309, 361	25, 569, 285	26, 019, 704	23, 860, 051
1882	26, 716, 188	27, 059, 611	27, 822, 825	28, 547, 481	29, 206, 697	29, 859, 952	30, 715, 144	31, 772, 094	32, 400, 303	32, 608, 533	33, 728, 555	34, 596, 612	30, 419, 499
1883	35, 187, 116	35, 692, 480	35, 881, 255	37, 789, 406	35, 755, 824	35, 985, 935	36, 371, 922	36, 164, 881	35, 752, 677	35, 613, 915	35, 506, 653	35, 745, 632	35, 953, 975
1884	35, 884, 509	36, 041, 898	36, 220, 270	36, 642, 794	38, 631, 203	38, 665, 838	38, 985, 767	39, 084, 561	38, 740, 734	38, 192, 317	37, 925, 756	37, 366, 126	37, 698, 481

Monthly and yearly average price of pipe-line certificates or crude petroleum at well for the years 1860–'84.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Averages.
1860	$19. 25	$18. 00	$12. 62½	$11. 00	$10. 00	$9. 50	$8. 62½	$7. 50	$6. 62½	$5. 50	$3. 75	$2. 75	$9. 59
1861	1. 00	1. 00	1. 00	. 62½	. 50	. 50	.50	. 25	. 20	. 10	. 10	. 10	. 49
1862	. 10	. 15	. 22½	. 50	. 85	1. 00	1. 25	1. 25	1. 25	1. 75	2. 00	2. 25	1. 05
1863	2. 25	2. 50	2. 62½	2. 87½	2. 87½	3. 00	3. 25	3. 37½	3. 50	3. 75	3. 85	3. 95	3. 15
1864	4. 00	4. 37½	5. 50	6. 56	6. 87½	9. 50	12. 12½	10. 12½	8. 87½	7. 75	10. 00	11. 00	8. 06
1865	8. 25	7. 50	6. 00	6. 00	7. 37½	5. 62½	5. 12½	4. 62½	6. 75	8. 12½	7. 25	6. 50	6. 59
1866	4. 50	4. 40	3. 75	3. 95	4. 50	3. 87½	3. 00	3. 75	4. 50	3. 39	2. 10	2. 12½	3. 74
1867	1. 87½	1. 85	1. 75	2. 07½	2. 35	1. 90	2. 62½	3. 15	3. 40	3. 55	2. 50	1. 87½	2. 41
1868	1. 95	2. 00	2. 55	2. 82½	3. 75	4. 50	5. 12½	4. 57½	4. 00	4. 12½	3. 75	4. 35	3. 62½
1869	5. 75	6. 95	6. 00	5. 70	5. 35	4. 95	5. 37½	5. 57½	5. 50	5. 50	5. 80	5. 12½	5. 63¾
1870	4. 52½	4. 52½	4. 45	4. 22½	4. 40	4. 17½	3. 77½	3. 15	3. 25	3. 27½	3. 22½	3. 40	3. 86
1871	3. 82½	4. 38	4. 25	4. 01	4. 60	3. 85½	4. 79	4. 66	4. 65	4. 82½	4. 25	4. 00	4. 34
1872	4. 02½	3. 80	3. 72½	3. 52½	3. 80	3. 85	3. 80	3. 58½	3. 25	3. 15	3. 83½	3. 32½	3. 64
1873	2. 60	2. 20	2. 12½	2. 30	2. 47½	2. 22½	2. 00	1. 42½	1. 15	1. 20	1. 25	1.00	1. 83
1874	1. 20	1. 40	1. 60	1. 90	1. 62½	1. 32½	1. 02½	. 95	. 95	. 85	. 55	. 61½	1. 17
1875	1. 03	1. 52½	1. 75	1. 36½	1. 40	1. 26½	1. 09	1. 13	1. 33	1. 32½	1. 44	1. 55	1. 35
1876	1. 80	2. 60	2. 01	2. 02½	1. 90½	2. 01¾	2. 24½	2. 71⅜	3. 81	3. 37½	3. 11	3. 73	2. 56¼
1877	3. 53¼	2. 70	2. 67½	2. 58	2. 24	1. 94⅝	2. 07½	2. 51	2. 38	2. 56¾	1. 91	1. 80	2. 42
1878	1. 43	1. 65¼	1. 59	1. 37½	1. 35¼	1. 14	. 98¾	1. 01	. 86⅝	. 82⅛	. 89⅜	1. 16	1. 19
1879	1. 03	. 98	. 86¼	. 78½	. 76	. 68⅜	. 69⅞	. 67⅛	. 69⅜	. 88⅛	1. 05⅝	1. 18⅛	. 85⅞
1880	1. 10¼	1. 03⅛	. 88¾	. 78	. 80	1. 00	1. 06¼	. 91	. 96	. 96⅞	. 91⅞	. 91⅝	. 94½
1881	. 95½	. 90⅜	. 83⅜	. 86¼	. 81⅞	. 81¼	. 76⅞	. 78⅛	. 97$\frac{3}{16}$	. 91¼	. 85¼	. 84⅜	. 85⅞
1882	. 83⅛	. 84½	. 81⅜	. 78⅜	. 71½	. 54⅜	. 57$\frac{4}{10}$	. 58⅝	. 72⅛	. 93¾	1. 14	. 96	. 78⅞
1883	. 93¾	1. 01	. 97⅝	. 92⅜	1. 00⅛	1. 16⅜	1. 05⅞	1. 08½	1. 12½	1. 11⅛	1. 14½	1. 14¾	1. 05¾
1884	1. 11	1. 04⅜	. 98⅛	. 94	. 85⅝	. 68⅝	. 63½	. 81⅛	. 78	. 71⅛	. 72½	. 74⅜	. 82½

THE PETROLEUM MARKET IN 1883 AND 1884.

During the past two years considerable fluctuations have taken place in the price of petroleum. The close of the year 1882 found the price rising slowly, as was expected when the depressing influence of the Cherry Grove gushers began to decline. There seemed to be but little possibility that another deposit similar to the Cherry Grove pool would be discovered, and with increasing confidence on all sides the price reached $1 per barrel in January 25, 1883, the highest attained since 1880. As time moved on various other circumstances in favor of higher prices, such as a disinclination to put down new wells, a falling off in the production of what wells were drilled, and an increase in consumption, together with the gradual reduction of the stock of petroleum on hand, increased the confidence of the trade to such an extent that in May a "boom" took place which resulted in raising the price to $1.20 at the close of that month, and on the first day of the succeeding month $1.24⅞ was registered on the exchanges. During the remainder of the year prices remained above the dollar line, nothing being developed in the oil fields to cause a downward movement. In the Balltown district, in Forest county, many large wells were producing, especially during September, but these wells were very short lived, declining in production from 1,000 barrels per day to less than 100 barrels per day within a space of a very few days.

The year 1884 opened with but little change in the situation. The developments in the Balltown and also in the Cooper districts continued, the wells exhibiting the same character as mentioned before, producing very largely at first, but rapidly falling off. This state of affairs continued until the month of March, when, under the influence of some unusually large developments in the Balltown pool and some indications that the Macksburg field, in Ohio, was tending in the direction of a large output, prices fell below $1 per barrel. This was followed in May by the financial troubles in New York. These troubles, together with the failure of the Penn Bank in Pittsburgh, an organization which had been dealing very largely in petroleum, affected the market very seriously, the price falling as low as 67 cents in May, a drop from which it seemed unable to recover, as in June; although the financial situation was much improved and field operations were restricted, the downward motion continued until 50 cents was reached. From this figure the market soon recovered to 60 cents, and fluctuated around this price until the latter part of July, when, under the influence of a serious decline in the production of the Wardwell tract, it rose to 75 cents, early in the succeeding month, August, reaching 80 cents.

During this month of August the most remarkable petroleum developments since the rise of the Cherry Grove field was made. The Baldridge district, on Thorn creek, had heretofore been a pool much resembling the Clarendon and Balltown pools, although considerably older. Wells of no small size had been struck in the district, but had invariably fallen off to small or medium producers. Early in August a well began drilling on Thorn creek by Phillips Brothers, which, upon striking the sand, commenced gushing at a rate of 300 barrels a day. This did not satisfy the owners, and the well was drilled deeper into the so-called fourth sand, upon reaching which depth the well began to produce oil at the rate of 1,800 barrels a day, according to moderate estimates. This important development affected the market seriously, prices falling very rapidly, and also caused a great rush of oil producers to Baldridge, or, as it began then to be called, Thorn creek. The Phillips Brothers' well did not fall off in production as had been expected, but continued to produce at an average of 2,000 barrels a day for over a month. Still more excitement was caused when the Christy well, not far from the Phillips well, was drilled into the sand on October 11, and began to produce oil at a rate of 1,500 barrels a day, which production it rapidly and wonderfully increased; two days later it was producing 2,500 barrels a day, and the next day was making the enormous production of from 5,000 to 6,000 barrels every twenty-four hours. These remarkable occurrences puzzled the oil trade greatly. When the Phillips well was making its large output, the theory was advanced that it was so situated as to draw the entire pool, and that any other wells that should be bored in the vicinity would simply decrease the production of the Phillips by the amount of their own output; but this and all other theories were disproved when, after nearly two months of production by the Phillips well, the Christy well came in and made its enormous output from an almost identical source. No one ventured to estimate the probable extent of the pool, and prices fell off with great rapidity. The Christy well, however, was not the largest producer that the Thorn Creek district was able to bring to the attention of the trade. Most of the wells in the district during the latter part of October had begun to decline, and with this encouragement the market began to recover its former position. True, 3,000 and 2,000-barrel wells were coming in frequently, but after the Christy well these producers did not appear so terrible as they did during the days of the Cherry Grove development. On Monday, October 27, however, the largest well ever known in the history of the New York and Pennsylvania oil fields was brought in. The Armstrong well No. 2 had been drilling into the sand the previous week and on Friday and Saturday was reported hopelessly dry. On Monday an 80-quart nitroglycerine torpedo was lowered into the hole and exploded. The result was startling; the well began to flow at a 3,000-barrel rate and within a few hours increased its output to the unheard of rate of 10,000 barrels a day, keeping up this immense production for some hours. The recent experience of the oil trade with large wells was of but little avail to it in the presence of so tremendous a gusher, and prices again declined rapidly, falling 14 cents in one day. The next day the Armstrong well declined considerably, producing about 7,000 barrels, and at the close of the week was putting out but a little over 5,000 barrels.

The success of the proprietors in the Armstrong well in "shooting" their well led to an extensive use of nitroglycerine throughout the Thorn Creek district. The result, however, was not the same, and it was finally conceded that the field was on the decline. From this time on, during the early months of 1885, no large developments were brought to light and other circumstances were favorable to an increase of price. Such seemingly had been the effects of the remarkable developments in the Thorn Creek field, however, that for several months in the face of these favorable circumstances prices remained at a low level, and it was not until near the middle of 1885 that any improvement took place.

Prices of petroleum in California have varied greatly. During a great scarcity of refined oil in 1865 it sold as high as $1.40 per gallon from first hands, and $1.75 from jobbers. Under ordinary circumstances, however, up to the close of 1869, the price was about 60 cents. A gradual reduction commenced, which reached its lowest point in 1883, when good brands were sold at from 15 to 17 cents. The price now varies from 25 to 30 cents. These figures all refer to the refined article. No information is at hand regarding prices of crude.

EXPORTS OF PETROLEUM.

Quantities and values of petroleum and its products, exported from the United States during the fiscal years 1875 to 1884 inclusive.

Mineral oil and products.	New York.		Philadelphia.		Baltimore.		Boston.		All other ports.		Total.	
	Gallons.		*Gallons.*		*Gallons.*		*Gallons.*		*Gallons.*		*Gallons.*	
Mineral, crude	11,055,615	$1,081,814	3,662,247	$324,116	....	....	....	....	252	$88	14,718,114	$1,406,018
Mineral, refined:												
Naphthas	9,405,412	948,098	1,830,696	147,018	400,329	$33,717	81,180	$8,118	41,323	3,889	11,758,940	1,141,440
Illuminating	118,825,486	17,507,286	52,411,429	6,724,172	17,608,320	2,281,732	2,227,142	397,545	479,556	119,626	191,551,933	27,030,361
Lubricating	388,545	104,611	260	50	376,677	82,280	400,966	124,119	7,085	2,586	1,173,473	313,646
Residuum	2,391,186	166,790	304,752	17,353	54,180	2,580	....	....	2,730	380	2,752,848	187,103
Total 1875	142,066,244	19,869,199	58,209,384	7,212,709	18,439,506	2,400,309	2,709,288	529,782	530,946	126,569	221,955,308	30,078,568
Mineral, crude	10,675,183	1,218,916	8,663,564	873,592	1,178,080	127,353	....	....	3,570	407	20,520,397	2,220,268
Mineral, refined:												
Naphthas	11,149,727	1,113,994	3,250,942	291,492	376,051	33,671	480	90	3,036	561	14,780,236	1,442,811
Illuminating	111,505,878	16,239,022	60,770,244	7,958,189	28,725,948	3,799,190	2,110,477	380,159	1,699,126	379,078	204,811,673	28,755,638
Lubricating	462,432	151,008	20,998	5,309	93,660	20,120	366,378	119,469	19,974	7,857	963,412	303,863
Residuum	2,286,564	171,905	278,166	19,736	8,358	738	....	....	8,316	827	2,581,404	193,206
Total 1876	136,079,784	18,894,905	72,983,914	9,151,378	30,385,097	3,981,672	2,477,335	499,718	1,734,022	388,713	243,600,152	32,915,786
Mineral, crude	21,127,100	2,988,996	4,262,093	538,101	1,111,617	171,200	....	....	318,392	38,432	26,819,202	3,756,729
Mineral, refined:												
Naphthas	10,915,337	1,363,433	3,499,300	378,412	633,105	64,224	87,093	9,145	5,348	1,468	15,140,183	1,816,682
Illuminating	165,327,149	35,017,416	50,823,652	10,757,806	35,876,575	7,472,443	3,671,122	860,418	6,743,346	1,293,019	262,441,814	55,401,132
Lubricating	907,456	273,481	22,269	6,143	165,206	41,421	440,644	151,823	65,490	24,672	1,601,065	497,510
Residuum	2,592,986	259,567	466,368	43,142	75,684	6,122	....	....	61,572	8,521	3,196,610	317,355
Total 1877	210,870,038	39,902,893	59,073,682	11,743,604	37,862,187	7,755,410	4,198,859	1,021,386	7,194,148	1,366,115	309,198,914	61,789,408
Mineral, crude	19,347,620	1,911,694	4,809,278	471,871	1,803,138	176,816	....	....	976,691	133,637	26,936,727	2,694,018
Mineral, refined:												
Naphthas	13,986,554	1,224,060	1,994,067	153,796	429,873	29,175	737	155	5,390	1,686	16,416,621	1,411,812
Illuminating	198,134,569	29,001,711	40,795,553	5,605,117	41,740,233	5,539,865	3,841,042	654,728	4,702,214	712,245	289,214,511	41,513,666
Lubricating	1,175,219	398,556	28,697	8,037	196,124	51,229	548,44	162,337	56,144	19,222	2,004,634	639,381
Residuum	3,526,866	284,706	178,878	13,598	....	....	....	....	263,046	17,783	3,968,790	316,087
Total 1878	236,470,848	32,820,067	47,806,473	6,255,419	44,169,368	5,797,085	4,391,119	817,230	6,003,515	884,573	338,841,303	46,574,974
Mineral, crude	17,716,883	1,517,701	4,687,786	377,197	1,166,825	98,292	....	....	2,302,994	187,223	25,874,488	2,180,413
Mineral, refined:												
Naphthas	11,477,029	987,145	2,729,037	207,928	100,782	42,500	52,750	4,623	194,763	16,584	15,154,361	1,258,780
Illuminating	266,520,009	23,088,504	70,307,729	7,795,749	32,662,045	3,231,700	5,090,871	640,553	11,005,788	1,243,356	385,586,442	35,999,862

	Gallons.		Gallons.		Gallons.		Gallons.		Gallons.		Gallons.	
Lubricating	1,709,556	$452,257	7,182	$3,367	263,759	$56,249	478,998	$134,903	22,186	$8,692	2,487,681	$655,468
Residuum	2,684,052	173,563	144,564	7,952	216,342	12,603	... .	..	262,080	16,518	3,307,038	210,726
Total 1879	240,107,529	26,219,170	83,876,298	8,392,193	14,915,753	3,441,434	5,622,619	780,079	13,787,811	1,472,373	378,310,010	40,305,249
Mineral, crude	24,034,260	1,652,200	2,750,147	160,549	....	....	500	65	1,533,090	114,393	28,297,997	1,927,207
Mineral, refined:												
Naphthas	15,257,520	996,398	2,360,622	148,464	682,702	36,200	385	93	103,815	11,074	18,411,044	1,198,229
Illuminating	266,841,227	23,489,496	77,083,630	6,234,608	17,921,518	1,399,975	4,611,433	507,511	867,985	151,985	367,325,823	31,783,575
Lubricating	4,151,597	822,388	34,913	6,980	367,240	68,713	600,837	137,378	8,218	3,665	5,162,835	1,039,124
Residuum	3,885,583	217,677	195,694	28,161	416,430	24,000	.....	..	69,888	6,652	4,767,000	270,490
Total 1880	314,170,192	27,178,159	82,610,436	6,578,762	19,387,920	1,528,888	5,213,155	645,047	2,582,996	287,769	423,964,699	36,218,625
Mineral, crude	34,032,428	2,661,708	5,326,528	351,736	....	....	7,156	687	618,732	51,333	39,984,844	3,065,464
Mineral, refined:												
Naphthas	16,103,509	1,581,154	1,084,324	95,516	...	......	26,954	2,779	77,523	14,526	17,292,310	1,093,975
Illuminating	254,360,615	26,334,465	55,076,050	5,480,763	13,881,990	1,327,989	7,808,194	962,437	1,216,156	211,541	332,283,045	34,317,695
Lubricating	3,851,572	842,214	154,836	30,169	266,237	50,167	572,922	128,695	6,636	1,789	4,852,203	1,654,064
Residuum	3,080,364	175,682	....	....	150,528	7,000	1,386	317	15,582	1,412	3,247,860	184,411
Total 1881	311,371,488	31,596,723	61,641,778	5,958,204	14,298,755	1,384,156	8,416,612	1,094,915	1,931,629	280,601	397,660,262	40,315,609
Mineral, crude	36,326,586	2,802,955	4,454,946	288,581	....	....	.. ..	....	523,465	37,975	41,304,997	3,129,511
Mineral, refined:												
Naphthas	18,941,538	1,515,809	3,172,703	273,848			13,860	3,081	84,997	16,405	20,213,098	1,809,143
Illuminating	342,424,705	31,794,515	116,322,347	9,993,605	18,188,946	1,438,189	8,903,437	1,022,455	2,373,608	340,390	488,213,033	41,588,854
Lubricating	5,249,902	1,235,846	764,663	131,443	147,997	24,522	275,122	76,282	70,716	21,303	6,508,100	1,492,396
Residuum	3,167,328	179,719	109,410	7,278	492,828	25,500	... .	....	5,796	335	3,715,362	212,802
Total 1882	404,050,059	37,528,834	124,823,759	10,697,435	18,829,771	1,488,211	9,192,419	1,101,818	3,058,582	416,418	559,954,590	51,232,706
Mineral, crude	45,470,118	3,453,182	6,959,240	460,857	....	....	... ..	....	282,948	20,902	52,712,306	3,914,941
Mineral, refined:												
Naphthas	15,160,731	1,167,332	1,752,328	104,187	...	.. ..	13,274	3,658	144,404	28,179	17,070,517	1,392,256
Illuminating	335,183,695	29,447,160	65,212,757	5,567,659	10,983,898	871,447	6,115,060	702,599	2,325,761	337,719	419,821,081	36,926,574
Lubricating	8,697,040	2,629,199	463,602	163,720	95,652	16,098	290,309	73,485	135,739	44,130	10,182,342	2,326,632
Residuum	5,658,276	409,984	240,366	15,882	227,976	15,573	....	...	8,778	1,267	6,145,356	442,640
Total 1883	410,179,620	36,485,857	75,128,293	6,312,265	11,307,436	903,118	6,418,643	779,742	2,897,630	432,127	505,931,602	44,913,079
Mineral, crude	61,622,893	4,961,448	5,557,310	460,853	....	....	....	... .	6,126	693	67,186,329	5,302,974
Mineral, refined:												
Naphthas	14,059,549	999,075	854,219	49,652	..	....	9,084	1,875	122,559	22,649	15,045,411	1,072,651
Illuminating	322,108,400	29,514,016	75,019,771	6,935,975	11,076,976	923,946	4,580,010	536,969	1,930,529	284,443	415,615,693	38,195,349
Lubricating	9,065,085	1,858,181	998,373	198,428	99,697	16,045	246,290	71,904	106,091	35,137	10,515,535	2,179,595
Residuum	4,470,060	378,512	176,736	9,050	630,882	32,217	10,164	960	9,222	1,910	5,297,124	352,679
Total 1884	411,325,987	37,581,132	83,506,412	7,593,338	11,807,549	972,238	4,845,548	611,708	2,174,596	344,832	513,660,092	47,103,248

Quantity of crude petroleum produced in, and the quantity and value of petroleum products exported from, the United States during the fiscal years 1864 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Production (*a*).		Exports.											
	Barrels (of 42 gallons) produced.	Gallons produced.	Mineral, crude (including all natural oils without regard to gravity).		Mineral, refined or manufactured.						Residuum (tar, pitch, and all other from which the light bodies have been distilled).		Total.	
					Naphthas, benzine, gasoline, etc.		Illuminating.		Lubricating (heavy paraffine, etc.).					
			Gallons.		*Gallons.*		*Gallons.*		*Gallons.*		*Gallons (b).*		*Gallons.*	
1864....	2,478,709	104,105,778	9,980,674	$3,864,187	438,197	$154,091	12,791,518	$6,764,411	....	....	....	....	23,210,368	$10,782,689
1865....	2,424,905	101,846,010	12,293,897	6,868,513	480,947	173,943	12,722,005	9,520,957	....	....	....	....	25,496,849	16,563,413
1866....	3,165,700	132,959,400	16,057,943	6,015,921	673,477	188,825	34,255,921	18,626,141	....	....	....	....	50,987,341	24,830,887
1867....	3,591,900	150,859,800	7,344,248	1,864,001	224,576	34,175	62,686,657	22,509,466	....	....	....	....	70,255,481	24,407,642
1868....	3,613,709	151,775,778	10,629,659	1,561,933	1,517,268	267,873	67,309,961	19,977,870	....	....	....	....	79,456,888	21,810,676
1869....	4,046,558	169,955,436	13,425,566	2,994,404	2,673,094	445,770	84,403,492	27,036,137	*c*134,532	$51,122	....	....	100,636,684	31,127,433
1870....	4,411,016	185,262,672	10,403,314	2,237,292	5,422,604	564,864	97,902,505	29,864,193	*c*6,871	2,611	....	....	113,735,294	32,668,960
1871....	5,558,775	233,468,550	9,859,038	1,971,847	7,209,592	746,797	132,608,955	34,138,736	*c*59,632	22,660	*c*155,474	$14,770	149,892,691	36,894,810
1872....	5,842,497	245,384,874	13,559,768	2,307,111	8,092,635	932,100	122,539,575	30,566,108	541,419	211,287	438,186	41,774	145,171,583	34,058,390
1873....	7,242,343	304,178,406	18,439,407	3,010,050	9,743,593	1,487,439	158,102,414	37,195,735	748,699	277,966	781,074	79,586	187,815,187	42,050,756
1874....	11,188,741	469,927,122	17,776,419	2,099,696	9,737,457	1,038,622	217,220,504	37,560,995	1,244,305	404,243	1,827,798	142,299	247,806,483	41,245,815
1875....	10,083,828	423,520,776	14,718,114	1,406,018	11,758,940	1,141,440	191,551,933	27,030,361	1,173,473	313,646	2,752,848	187,103	221,955,308	30,078,568
1876....	8,823,142	370,571,964	20,520,397	2,220,268	14,780,236	1,442,811	204,814,673	28,755,638	963,442	303,863	2,581,404	193,266	243,660,152	32,915,786
1877....	10,822,871	454,560,582	26,819,202	3,756,729	15,140,183	1,816,682	262,441,844	55,401,132	1,601,065	497,540	3,196,620	317,355	309,198,914	61,789,438
1878....	14,738,262	619,007,004	26,936,727	2,694,018	16,416,621	1,411,812	289,214,541	41,513,676	2,304,624	639,381	3,968,790	316,087	338,841,303	46,574,974
1879....	16,917,606	710,539,452	25,874,488	2,180,413	15,054,361	1,258,780	331,586,442	35,999,862	2,487,681	655,468	3,307,038	210,726	378,310,010	40,305,249
1880....	22,382,509	940,065,378	28,297,997	1,927,207	18,411,044	1,192,229	367,325,823	31,783,575	5,162,835	1,039,124	4,767,000	276,490	423,964,699	36,218,625
1881....	25,805,303	1,083,825,246	39,984,844	3,065,464	17,292,310	1,693,975	332,283,045	34,317,695	4,852,203	1,054,064	3,247,860	184,411	397,660,262	40,315,609
1882....	28,650,181	1,203,307,602	41,304,997	3,129,511	20,213,098	1,809,143	488,213,033	44,588,854	6,508,100	1,492,396	3,715,362	212,802	559,954,590	51,232,706
1883....	26,662,808	1,119,837,936	52,712,306	3,914,941	17,670,537	1,302,286	419,821,081	36,926,574	10,182,342	2,326,632	6,145,356	442,646	505,931,622	44,913,679
1884....	23,744,924	997,286,808	67,186,329	5,302,974	15,045,411	1,072,651	415,615,693	38,195,349	10,515,535	2,179,595	5,297,124	352,679	513,660,092	47,103,248

a As a given number of gallons of refined petroleum represents the product of a larger number of gallons of crude petroleum, it is necessary to reduce the exports of petroleum to their equivalent in crude oil, in order to arrive at a knowledge of the percentage of the total product of mineral oil exported. It has been ascertained, as the result of a careful computation, that the quantity of petroleum and its distilled products exported during the year ended June 30, 1878, was equivalent to 467,482,175 gallons of crude oil; or in other words, that the exports of petroleum constituted about 66 per cent. of the production. A larger percentage of the mineral oil product of the country is exported than of any other product, except cotton.

b Barrels reduced to gallons, at the rate of 42 gallons to the barrel.

c Estimated.

FOREIGN SOURCES OF PETROLEUM.

Russia.—The petroleum district on the Caspian sea, in the vicinity of Baku, has within the past few years attracted much attention. Not that it has recently been discovered, for as early as the reign of George II. of England the petroleum produced here was an article of commerce. Statistics show that in 1813 3,000 tons of oil were exported from Baku. Recent attention to this field has rather been caused by the gradually increasing competition between this oil and American petroleum, rendered possible by the greatly increased development of the field since 1872.

The oil fields in this locality have an area of about 14,000 square miles. But little is known of the geology of the region, but from the data at hand in regard to the depth and proximity of producing wells throughout the district, the inference must be drawn that there exists no single large pool of oil under the surface. There seems to be no common depth or horizon from which the oil is drawn—none even as regards wells in very close proximity to each other. Thus recently, in one locality, there were four producing wells within a few yards of one another, yet all producing from different depths, the first striking oil at 259 feet, the second at 560 feet, the third at 280 feet, and the fourth at 350 feet. It has also been noticed that a flowing well may be struck in the immediate vicinity of a pumping well, and will produce immense volumes of oil, the pumping well at the same time continuing to produce its regular quantity without any diminution whatever. All accessible facts appear to demonstrate the theory that the oil-bearing strata, originally running regularly in an almost vertical position, became dislocated by some dynamic agency, and an irregular cellular character was thus given to the petroleum deposits.

The flowing wells or fountains, as they are very properly called, are a very remarkable feature. These cast into the shade American "gushers." The largest production of an American oil well on record is that of the Armstrong well, in the Thorn Creek district of Pennsylvania, which in 24 hours produced 10,000 barrels or 420,000 gallons. The largest product of a Russian well on record is 2,000,000 gallons in 24 hours, nearly five times the best American record. Flowing wells yielding from 1,000 to 4,000 barrels per day, rarities in Pennsylvania, are common at Baku, and the ordinary yield of "pumpers" is from 250 to 600 barrels per day, many of these continuing their production for years without diminution. Fountains also frequently have great staying powers, one being struck in 1879 which for three months spouted oil at the rate of 4,000 barrels every 24 hours without cessation, a production which no American well has ever kept up for more than a few days.

For many years the production of petroleum at Baku was a crown monopoly, and heavy taxes were also levied on it. Owing to these repressing influences, in 1872, when the monopoly was abolished, there were but two drilled wells in the region, the oil being derived generally from shallow pits, of which there were 415 in the district.

The following statistics show clearly the rapid rise of the industry since 1872, and especially since the repeal of the excise duties in 1877. The pood contains about 4 gallons, and is hence about one-tenth of a barrel.

Production of petroleum in the Baku district since 1840.

Years.	Poods.	Years.	Poods.
1863	340, 000	1874	4, 862, 643
1864	538, 000	1875	5, 819, 043
1865	554, 291	1876	11, 000, 000
1866	691, 820	1877	15, 000, 000
1867	698, 9[illegible]7	1878	20, 000, 000
1868	735, 764	1879	23, 000, 000
1869	1, 685, 229	1880	25, 000, 000
1870	1, 704, 465	1881	30, 000, 000
1871	1, 375, 523	1882	37, 800, 000
1872	1, 535, 981	1883	50, 000, 000
1873	3, 951, 575		

The following figures give the number of wells in the district for certain years in the past:

Number of wells in the Baku district at different periods.

Years.	Wells.	Years.	Wells.
1871	1	1876	101
1872	2	1879	301
1873	17	1882	370
1874	50	1883	400
1875	65		

Transportation facilities are good at Baku. Much of the petroleum produced is run directly into vessels on the Caspian sea, which are practically huge floating tanks, and thence conveyed to the mouth of the Volga river. Hence it is distributed to many localities. Much of it is used for fuel by the steamers on the Volga, as well as by the oil transports themselves. The railroads are beginning to utilize it as fuel. It finds its way throughout Russia, Poland, and Finland, and has recently been competing with American petroleum in Germany. The latter article, handicapped by import duties, is likely to find a serious competition in Russian oil.

Some two hundred refineries exist in the Baku district, much of the petroleum being refined on the spot.

Other countries.—In many other foreign countries petroleum is found, though no deposits equal to the Russian fields are known. Among those in which districts of greater or less importance exist may be named Germany, Spain, Sicily, Roumania, Afghanistan, China, Japan, India, Burmah, and New Zealand. At various places in South America, and in many of the West India islands, it is known to exist. In Canada, and also in Mexico, petroleum is found, in the former country many wells existing, and quite a large quantity of oil being produced.

NATURAL GAS.

Estimated consumption.—The total consumption of natural gas issuing from numerous wells in the western part of Pennsylvania and in the adjacent parts of New York, Ohio, and West Virginia, during the calendar years 1882, 1883, and 1884, has been estimated, as follows, from detailed statements by Mr. T. P. Roberts, of Pittsburgh:

Estimated value of natural gas consumed in 1882, 1883, *and* 1884.

Years.	Pittsburgh region.	Elsewhere.	Total.
1882	$75,000	$140,000	$215,000
1883	200,000	275,000	475,000
1884	1,100,000	360,000	1,460,000

These values are based upon the value of the coal that has been supplanted in furnaces now using gas. Although it is possible to estimate roughly the volume of gas consumed in these furnaces by considering the average number of cubic feet of gas which replace a ton of coal, in cases where this quantity has been measured, such an estimate will give no idea of the total production, since a very large amount is wasted when not in use in the furnaces, no provision having been made for storage. Hitherto it has not been the usual practice to meter the gas. It is possible that the production of future years can be obtained in cubic feet. The consumption in the Pittsburgh region for 1882 and previous years was limited to the Etna Iron Works, of Messrs. Spang, Chalfant & Company. During the latter part of 1883 gas began to be used more generally in the various iron and glass works of Pittsburgh.

The following account of the natural gas industry has been compiled mainly from notes furnished by Mr. W. S. Jarboe, of Pittsburgh:

Characteristics.—Natural gas obtained from the wells in Pennsylvania and elsewhere consists principally of the hydrocarbon "marsh gas," so-called because of its frequent occurrence among the products of vegetable decay. This marsh gas, which rises from stagnant pools, contains, however, nitrogen and carbonic acid in larger quantities than natural gas from deep borings. Natural gas contains small quantities of other hydrocarbons, such as ethane and propane, and traces of the vapor of less volatile members, all of the paraffine or petroleum series, of which marsh gas is the first member. In addition to these the gas contains hydrogen and traces of carbonic acid, carbonic oxide, oxygen, and nitrogen.

It has been stated that ethylene and other hydrocarbons of the series known as "olefines," which give the illuminating power to coal gas, occur; but the evidence upon this point goes to prove the contrary, for the work of S. P. Sadtler in 1875, and of several later analysts, has shown that no trace of addition products can be obtained by passing large quantities of gas through bromine, except with gas from the northern portion of the field. The presence of ethane and propane has been shown by separating them with absolute alcohol, through which a large quantity of gas was passed. When taken from the wells the gas has a peculiar odor like that of naptha; it disappears if the gas is left for a number of hours in a closed vessel; the odor is probably due to traces of vapor of hydrocarbons higher than propane in the paraffine series. The tables of analyses show the variations in composition of natural gas from various sources. Although there may be some question as to the care taken in determining the proportion of ethane, propane, and hydrogen in some of these analyses, they afford valuable proof of the fact that in all the sources marsh gas is the important constituent.

Analyses of natural gas.

	Petrolia, Canada. (a)	West Bloomfield, New York. (b)	Olean, New York. (c)	Fredonia, New York. (d)	Pioneer Run, Venango county, Pennsylvania. (e)	Burns well, near Saint Joseph, Butler county, Pennsylvania. (f)	Harvey well, Butler county, Pennsylvania. (g)	Cherry Tree, Indiana county, Pennsylvania. (h)	Leechburg, Armstrong county, Pennsylvania. (i)	Creighton, Allegheny county, Pennsylvania. (j)	Penn Fuel Company's well, Murrysville. (k)	Fuel Gas Company's well, Murrysville, Westmoreland county, Pennsylvania. (l)	Roger's Gulch, Wirt county, West Virginia. (m)	Gas from marsh ground. (n)	Baku, on the Caspian sea. (o)	Gas occluded in Wigan cannel coal. (p)	Blower in coal mine, South Wales. (q)
Hydrogen	Chiefly marsh gas with ethane and some carbonic acid.	......	......	A mixture of marsh gas, ethane, and butane.	Chiefly propane with small quantities of carbonic acid and nitrogen.	6.10	13.50	22.50	4.79	......	Marsh gas with a little carbonic acid.	19.56	Chiefly marsh gas, with small quantities of nitrogen and 15.86 per cent. carbonic acid.	......	0.98	......	......
Marsh gas		82.41	96.50			75.44	80.11	60.27	89.65	96.34		78.24		47.37	93.09	80.69	95.42
Ethane		......	......			18.12	5.72	6.80	4.39	......		......		......	......	4.75	......
Propane		......	......			trace.	......	......	trace.	......		......		......	......	......	......
Carbonic acid		10.11	......			0.34	0.66	2.28	0.35	3.64		......		3.10	2.18	6.44	0.60
Carbonic oxide		......	0.50			trace.	trace.	trace.	0.26	Trace of heavy hydrocarbons.		......		......	......	......	......
Nitrogen		4.31	......			......	......	7.32	......			......		49.39	0.49	8.12	3.98
Oxygen		0.23	2.00			......	......	0.83	......			2.20		0.17	......	......	......
"Illuminating hydrocarbons"		2.94	1.00			......	......	......	0.56			......		......	3.26	......	......
	......	100.00	100.00	......	......	100.00	99.99	100.00	100.00	......	......	100.00	......	100.03	100.00	100.00	100.00
Specific gravity	......	0.693	0.692	......	......	0.6148	0.5119	......	0.5580	0.5923	0.56	......	......	......	......	......	......

a Fouqué, *Comptes Rendus*, lxvii, p. 1045.
b H. Wurtz, *Am. Jour. Arts and Sci.* (2), xlix, p. 336.
c Robert Young.
d Fouqué, *Comptes Rendus*, lxvii, p. 1045.
e Fouqué, *Comptes Rendus*, lxvii, p. 1045.
f S. P. Sadtler, Report L, 2d Geol. Sur. Pa., p. 153.
g S. P. Sadtler, Report L, 2d Geol. Sur. Pa., p. 152.
h S. P. Sadtler, Report L, 2d Geol. Sur. Pa., p. 153.
i S. P. Sadtler, Report L, 2d Geol. Sur. Pa., p. 153.
j F. C. Phillips.
k Robert Young.
l Rogers.
m Fouqué, *Comptes Rendus*, lxvii, p. 1045.
n Bischof's "Chemical Geology," I, p. 730.
o Bischof's "Chemical Geology," I, p. 730.
p J. W. Thomas, *London Chem. Society's Journal*, 1876, p. 793.
q Same, 1875, p. 793.

Occurrence — Natural gas has been found in varying quantities in New York, Pennsylvania, West Virginia, Ohio, Illinois, Kentucky, Alabama, Kansas, Dakota, and California.

In New York it has been found in Ontario, Allegany, Cattaraugus, and Chautauqua counties.

In Pennsylvania in Erie, Warren, McKean, Forest, Venango, Clarion, Butler, Armstrong, Lawrence, Beaver, Allegheny, Westmoreland, and Washington counties.

In West Virginia in Hancock, Brooke, Ohio, and Marshall counties.

In Ohio in Jefferson, Cuyahoga, Wayne, Knox, Crawford, Hancock, and Wood counties.

In Illinois in Champaign county.

In Kentucky in Meade and Martin counties.

In Kansas in Miami county.

In Dakota in Davison county.

In California in Los Angeles and San Joaquin counties.

Since crude petroleum is a mixture of hydrocarbons ranging in practically unbroken series from solid paraffine down to the most volatile liquids, and even containing the gaseous members such as marsh gas and ethane in solution, natural gas is looked for in regions where petroleum is found; and although it has been obtained outside of the petroleum localities, it is found in the same sandstone formations which yield petroleum. Until 1883 nearly all the gas wells in Pennsylvania had been discovered in the effort to obtain oil. The same methods of drilling wells have been used as for petroleum. The cost of a well is about the same as that given for petroleum wells in "Mineral Resources of the United States, 1882," page 196. Gas wells vary in depth from slight excavations at Fredonia, New York, made in order to confine gas which had already reached the surface through natural vents, to wells more than 2,000 feet deep, in which gas was found 500 to 1,000 feet below the second oil sand. Ordinarily the wells in Pennsylvania vary from 1,100 to 1,400 feet in depth according to the surface configuration above the second Venango oil sand, in which it is claimed by Prof. I. C. White that all the important wells are found. The following are records of strata passed through in drilling some typical wells:

Section traversed in the Tarentum field, Allegheny county, Pennsylvania.

Character.	Feet.		Character.	Feet.	
Surface formation	0 to	16	Slate	411 to	423
Slate	16	46	Sand	423	598
Bluff	46	106	Very strong salt water at		449
Slate	106	206	Sand, "shell," and slate	598	860
Very sharp close sand	206	296	Hard white sand	860	905
Slate	296	336	Slate with hard "shell"	905	1,147
Sand	336	411	Heavy flow of gas at		1,147

Section of well in Murrysville district, Westmoreland county, Pennsylvania.

Character.	Feet.		Character.	Feet.	
Sand and slate	0 to	270	Light blue sand	965 to	1,000
Coal	270	278	Dark blue sand	1,000	1,130
Sand and slate	278	440	Red slate and hard yellow "shell"	1,130	1,150
Fine, bluish gray sand	440	530	Blue slate and "shell"	1,150	1,270
Slate	530	567	Soft slate	1,270	1,285
Red rock	567	573	Sandy slate	1,285	1,312
Yellow sand and clear salt water	573	590	Soft black slate	1,312	1,315
Slate	590	605	Hard white sand	1,315	1,337
Dry, yellowish white sand	605	663	Slate and streaks of sand	1,337	1,414
Sand and slate	663	710	Soft slate	1,414	1,416
White sand	710	960	Top of gas sand		1,416
Slate	960	965			

Section traversed by a gas well at Wellsburg, West Virginia.

Character.	Feet.		Character.	Feet.	
Yellow clay	....	....	Fourth gas vein		400
Blue clay	20 to	40	Sandstone	388 to	403
First gas struck		45	Cased		410
Gravel	40	72	Slate and shale	403	478
Casing		72½	Fifth gas vein		535
Blue sandstone	72	78	White sandstone	478	553
Second gas vein	....	....	Salt water	....	....
Black slate	78	113	Gray sandstone	553	583
Fireclay	113	135	Blue sandstone	583	623
White sandstone	135	147	Coal	623	629
Fireclay	147	187	Slate	629	660
Slate	187	199	Sixth gas vein		750
Coal	199	204	White sandstone	660	800
Cased off first water		208	Slate	800	850
Fireclay	204	214	Salt water		870
Slate	214	234	White sandstone	850	900
Slate and shale	234	274	Seventh gas vein	....	....
Third gas vein		287	Erie shale	900	1,300
Cased again		300	White sandstone	1,300	1,310
White sandstone	274	314	Large flow of gas		1,310
State	314	388			

In regard to the occurrence of gas outside of the oil district, Prof. Edward Orton (*a*) says of the wells in northwestern Ohio: "I have lately examined the carefully kept records of six of these wells [in Hancock and Wood counties]. They agree entirely in their main features. All begin in the Upper Silurian limestone, and all find their main supply of gas in the Trenton limestone. The section furnished by them is as follows:

Character.	Feet.	Character.	Feet.
Niagara limestone, gray and blue, dolomitic	200	Medina shale, red and blue	50–100
Niagara clay, a characteristic bed in central Ohio	2–4	Hudson River shale, gray and blue	400–700
Clinton limestone and shale, highly colored	75	Utica shale, dark, almost black in places.	275
		Trenton limestone	300
		Bird's-eye limestone	(?)

"The Trenton limestone was drilled through in but a single well. The gas obtained from the wells is delivered with moderate pressure. It contains a notable quantity of sulphureted hydrogen."

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a *Science*, vol. 5, page 474.

History.—The fact that an inflammable gas issues from certain springs and also from fissures in the earth has been recognized for a very long time, but the first recorded use of such gas for the purposes of illumination, etc., was at Fredonia, Chautauqua county, New York, in 1821. The gas was obtained from a spring on the north bank of Canadaway creek in the village. The spring was excavated to a slight extent, covered, and the gas conveyed to a small copper holder, and thence piped to a mill and several stores for illumination. The gas from this well, which was sufficient for thirty burners, was used alone until 1858, when another well was sunk in the northwestern part of the village. The new well consisted of a shaft 30 feet deep, 6 feet wide at the top, and 14 feet at the bottom, with two vertical borings, one 100 feet and the other 150 feet deep. In 1865 the Colburn well, 1,250 feet deep, was added to the Fredonia supply, which at present amounts to 6,000 cubic feet per day. After gas was found at Fredonia, such occurrences were frequently noticed and sometimes used.

In 1823 Mr. John Klingensmith, sr., while drilling for brine on Brush creek, 4 miles from Greensburg, Pennsylvania, struck a crevice in which so much gas was found that it took fire and burned the cabin in which the men slept. Judge Campbell, of Westfield, New York, supplied the light-house at Barcelona, a small harbor on Lake Erie, from a spring of natural gas, by contract with the National Government, until the light-house was abandoned, in 1856. In 1827 it was proposed to supply the light-house at Dunkirk, New York, with gas from the Matteson spring at Fredonia, but the project was abandoned from difficulty in transporting the gas. The numerous borings for oil at Titusville, Pennsylvania, in 1859–'60, yielded more or less gas as well as oil. Public notice was first directed to its quantity by the burning of the Rouse well on Oil creek, where a large number of lives were lost by the explosion of gas. It was then considered more of a nuisance than an article of value; little was used as fuel, and it was usually piped from the wells to a safe distance to dispose of it by burning. In 1867 two wells were bored near Rocky river in the village of East Rockport, near Cleveland, Ohio, which have since that time supplied about twenty houses with light and partly with heat.

The use of waste gas from the Pennsylvania oil wells began in 1872 or 1873, in Butler county, when the Fairview well, 1 mile west of Petrolia, was connected by pipes with Fairview, Petrolia, Argyle, and Karns City; in 1873 40 boilers, 8 pump stations on the lines, 200 gas burners, and 40 cooking stoves were fed from this well. Many large wells have since been struck in Butler county. Prominent among them are the Burns well, on the Delphy farm, three-fourths of a mile south of Saint Joe; the Delamater well, one-half mile from the former; the Harvey well, near Larden's Mills, Clinton township; Saxon Station well, Winfield township; these were bored in 1874 and are still valuable, the last mentioned supplying half of its village with heat, besides being utilized for the manufacture of lampblack. Since 1874 twelve other wells have been bored in Butler county, and have been used in supplying the plant of Spang, Chalfant & Co., being piped 18 miles to their mills near Pittsburgh. In these mills gas is now used under twelve boilers, in nine heating furnaces, and in twenty-eight puddling furnaces. Some of the oldest of these wells are still furnishing large amounts of gas; others failed after four to six years' use. Several other wells have been drilled in Butler county within the last two years, and the region is still being developed actively. In 1872 the gas from the Titusville oil region was led from Newton well, in Oil Creek township, Crawford county, to Titusville and introduced into dwellings, refineries, etc. The flow decreased, however, until it finally was of no use. With the exception of this transient use in Crawford county the development of the gas industry in Pennsylvania followed a circular path, with Pittsburgh at its center. From Butler county the discovery of gas wells extended to Kittanning, Armstrong county, in 1876. In 1880 a well was applied to the rolling mill of the Kittanning Iron Company. Developments at this place have been continued. In June, 1883, a second well was finished, adjoining the old one, and in September, 1884, a third was added to the supply of the rolling-mill, where thirty-six puddling furnaces and eighteen boilers consume, in all, perhaps, 1,000,000 cubic feet of gas per hour. In 1878 an enormous volume of gas was found in a well on the Remaly farm, at Murrysville, Westmoreland county. In August, 1882, a second well was bored, and in April, 1883, another on Lyon's run. The gas from these wells was piped to Pittsburgh, by the Penn Fuel Company. The Fuel Gas Company finished two wells in the same region in 1883, and by consolidation all these wells were connected with Pittsburgh, and began to supply that city with natural gas. In 1883 the Acme Gas Company drilled a well on Remaly farm, but did not get enough gas to pay for piping it. Their next venture on Lyon's run was more successful. According to Messrs. Boulton and Doubleday, of the Acme Company, several wells have been drilled as far as the gas sand, and only require a few hours' work to produce gas when it is needed. This company has an 8-inch wrought-iron pipe, 8 miles long, from their wells to the Edgar Thomson Steel Works (Carnegie Bros.), at Bessemer station, on the Pennsylvania railroad, and thence a 6-inch pipe to the Pittsburgh Bessemer Steel Company at Homestead, on the south side of the Monongahela river. When the Edgar Thomson works are running to the full capacity the gas consumed takes the place of 400 tons of coal per day. According to Capt. William Jones, the consumption at the Homestead works is equivalent to 300 tons of coal per day. The Acme Company also supplies one glass house, the boilers at the poor farm, and is now introducing pipes into Braddock for heating and lighting. According to Mr. Scott Verner, the Carpenter Natural Gas Company has increased the yield of Westmoreland county by a well on the Daum farm, in Penn township, from which gas is piped to

Pittsburgh and McKeesport. Mr. J. G. Beale reports that a well was bored at Leechburg, Armstrong county, in May, 1880, which was supplemented in 1882 by a well on the opposite side of the river. Both of these are controlled by the West Penn Steel Works, and either is sufficient for supplying the whole plant, taking the place of 1,000 bushels of coal daily in one open-hearth furnace of 10 tons capacity, one heating furnace, and one hammer furnace. The town of Leechburg has a well supplying three hundred or four hundred fires, two grist mills, and eight boilers, at an income of about $500 per month. The celebrated McGuigan well, 2 miles from the town of Hickory, began the development of the industry in Washington county. It was drilled for oil to the unusual depth of 2,257 feet, in March, 1881. Since the inclination to substitute gas for coal has been fairly established in Pittsburgh, this well has been furnishing gas to some of the manufactories on the south side, to Weighman's glass house, and J. Painter's Sons & Co.'s rolling mill. In the last mill alone the gas will replace a daily consumption of 6,500 bushels of coal when running to the full capacity. In 1884 the Emery and Miller wells were drilled in the Washington County region, and besides these three large wells, the People's Light and Heat Company, of Washington, owns two small wells, used for heating and lighting that town.

During 1883 and 1884 the borings for gas wells were numerous and scattered over a large area. They have resulted in the location of two important fields, one at Pittsburgh itself and the other the great Tarentum region, in Allegheny county. In regard to the latter, it should be said that its discovery was not an accidental consequence of boring for oil, but the result of continued effort to obtain natural gas. Mr. J. B. Ford in seeking gas for a plate-glass factory to be erected at Creighton station, Western Pennsylvania railroad, drilled a well within 170 feet of what became the celebrated well of Graff, Bennett & Co. at Tarentum, but obtained nothing. His next venture was nearer the proposed glass house, and was abandoned at 2,309 feet. Not daunted by two failures, Mr. Ford succeeded in finding a good well on the farm of James Smith, on Big Bull creek, back of Tarentum. Another good well was found on J. S. Coe's farm, East Deer township, Allegheny county. These supply two 400 horse-power engines, 14 double-cylinder engines of 20 horse-power each, 60 annealing ovens, furnaces melting 30 tons of glass daily, and 50 dwelling houses. Since the Coe well the Pennsylvania Salt Manufacturing Company has drilled one small well, one dry well, and one well equal to the Coe. Richards & Whiteley, glass manufacturers, have a large well, which they bored in 1883. The Tarentum Light and Heat Company struck two good wells. Messrs. Guffey & Galey drilled two wells in this field, the first about equal to the Coe, and the second one of the largest ever found. The latter has been sold to the Philadelphia company of George Westinghouse & Co., and is being piped to Pittsburgh. In September, 1883, another very large well was drilled on the Crist farm, about 1 mile from Tarentum. It is owned by capitalists, who propose to utilize it for manufacturing. A number of other wells are drilling in this field. The immediate vicinity of Pittsburgh was considered a salt-water district, on account of the several large salt-water wells drilled by the salt manufacturers and by the record of the deep well drilled on Boyd's hill. This well was begun early in 1876, and at a depth of 1,588 feet a conglomerate was found, supposed to be the upper Berea grit; from this depth to 1,700 feet the same strata extended and produced an immense volume of salt water, 11° strong. The flow was estimated to be about 3,000 to 4,000 barrels per day. The well was drilled to 2,300 feet, but no oil or gas was found in any quantity. On May 29, 1884, Mr. Westinghouse struck an immense gas well on his premises at Homewood, inside of the limits of Pittsburgh. This well when first struck showed a pressure of 15 to 17 pounds when blowing freely from a $5\frac{5}{8}$-inch pipe; but it began to diminish, and twenty-one days from the day it was struck it had lost 60 per cent. of its flow, and in October, 1884, it had settled down to an ordinary well. Its flow when first struck was estimated to be about 20,000,000 cubic feet per day. Westinghouse No. 1 was plugged with long wooden plugs at the gas horizon, so as to allow the well to be reamed out down to the gas. When the plug was drilled out, the force of the gas was so great that the plug, drill, and all, weighing in the neighborhood of 3,600 pounds, were blown from the well through and above the derrick. This strike started a perfect furore in gas drilling. A well was started on the Park Bros. & Co.'s lot, Thirty-first street; others at Moorhead & McClain's, Jones & Laughlin's, Chess, Cook & Co.'s, and Painter's mill. These all proved to be salt-water wells. The Fuel Gas Company's venture, about 1,000 feet nearly due east from No. 1, proved to be a dry hole. Around Homestead many more wells were started. Mr. Westinghouse started Nos. 2, 3, and 4. The Penn Fuel Company obtained a small well, the Fuel Gas Company a dry hole, and Dillworth Bros. a small well. Messrs. J. M. Guffey & Co. drilled a well about one-half mile northeast from Westinghouse No. 1, and got a very fair yield of gas. Several wells at Brushton station were bored, but yielded little gas. A fair well was obtained by Mr. Howard Morton, on Four Mile run, in October, 1884, at a depth of 1,715 feet; but in attempting to increase the yield, salt water was struck and ruined the well. This was also the history of two wells at Elrod's station, Baltimore and Ohio railroad. New wells are constantly being added to this Pittsburgh region.

Besides the local wells the Butler county, Murrysville (Westmoreland county), Washington county, and Tarentum regions supply gas for Pittsburgh. The greater part of this gas has been brought from the Murrysville district by the Penn Fuel Company's and the Fuel Gas Company's lines. The former has one 8-inch line and one $5\frac{5}{8}$-inch line. The latter has two $5\frac{5}{8}$-inch lines. These two companies have united, and are now laying a 10-inch line in addition to the four in use. This combination alone has supplied the following list of consumers; the list shows the number of puddling furnaces, boilers, leers, glory holes, brick kilns, etc.:

Furnaces, etc.	No.	Furnaces, etc.	No.	Furnaces, etc.	No.
Boilers	168	Leers	76	Drying floors	4
Open-hearth furnaces	6	Other small furnaces	30	Ladle burners	7
Crucible furnaces	10	Bakers	3	Blow furnaces	12
Puddling furnaces	85	Mufflers	2	Flattening ovens	6
Heating furnaces	83	Annealers	62	Bending furnaces	4
Sand furnaces	4	Core ovens	22	Lap-weld furnaces	2
Hammer furnaces	10	Japanning ovens	2	Butt-weld furnaces	4
Glass-melting furnaces	7	Calcining ovens	2		
Glory holes	55	Brick kilns	29		

Although the sources given thus far represent the most important features of the industry, inasmuch as they supply Pittsburgh, the use of natural gas has lately been extended to several other districts, some of them far removed from Pennsylvania. In 1884 two wells drilled on Raccoon creek in Hopewell township, Beaver county, were used to supply the towns of Philipsburg, Beaver, Rochester, New Brighton, and Beaver Falls, and several other wells are to be drilled in the same locality. More than sixty wells have been drilled in and around Erie, Pennsylvania. The number of companies chartered to supply natural gas in Pennsylvania up to February 5, 1884, was one hundred and fifty, representing a capital stock of $2,160,580. Since that date a large number of new charters have been granted.

In West Virginia the Barclay well was bored expressly for gas near Wellsburg, and has been used for supplying that town with light and heat; it furnishes fuel for a paper mill, the water works, a machine shop and planing mill, a nail and rolling mill, and some two hundred and fifty dwellings, besides churches, halls, etc. Of six other wells in this district four are valuable. Across the river, at Brilliant, a similar well is also in use. At Moundsville, Marshall county, gas was found in the spring of 1883 by a party of Pittsburgh capitalists while drilling for oil. The well was ruined by boring deeper and striking salt water.

In Ohio gas wells have been known for twenty years or more at East Liverpool and New Cumberland; in 1884 they were applied to heating and lighting those towns. In Cleveland the Brush Electric Light Company is using gas from a private well, and the Cleveland Rolling Mill is boring one. The Jefferson Iron Works finished a well for their use at Steubenville in 1883. Crestline and Wooster also have gas wells, and gas companies have recently been formed in Toledo, Painesville, Findlay, and Ashtabula. The Cincinnati Warehouse and Malting Company has discovered gas in a well bored for water to a depth of 256 feet; the company is preparing to use the gas for heating purposes and eventually for lighting the building.

Natural gas is known in Kentucky near Louisville, near Warfield, in

Martin county, and at Paducah; in Indiana, at Vernon; in southern Illinois at Metropolis, in Massac county; in Alabama, near Village creek; in Miami county, Kansas, 6½ miles east of Paola (according to Mr. E. C. Wickersham, of the Paola Gas Company, this well is to be connected with Paola for illuminating purposes); at Mitchell, Davison county, Dakota; and near Stockton, San Joaquin county, and in Los Angeles county, California.

The following towns, among others, were using natural gas for domestic and manufacturing purposes at the close of 1884:

New York—Olean, Wellsville, Bolivar, Richburg. Rochester, Cuba, Fredonia, and Gasport.

Pennsylvania—Pittsburgh, Allegheny, Washington, Kittanning, Oil City, Titusville, Foxburg, Erie, Clarion, Parker, Bradford, Freeport, Butler, Tarport, Braddock, Tarentum, Manorsville, Creighton, Fairview, Petrolia, Argyle, Karns City, Warren, and McKeesport.

West Virginia—Wellsburg.

Ohio—Cleveland, East Liverpool, Steubenville, and Wooster.

Foreign occurrences.—Natural gas has been found in considerable quantity at Baku, on the Caspian sea, at oil wells drilled by Messrs. Nobles. In China gas has been used for years in the district of Tsien Luon Tsing. The gas is said to come from the great depth of 3,000 feet. It is carried away in bamboo pipes and burned from these pipes by means of clay pipe burners. These are the oldest wells on record. No record can be found as to the method used in drilling them.

Use.—Natural gas has thus far been used more as a source of heat than of light. The question of its use for heating purposes depends primarily upon the temperature which can be obtained with it under the most favorable conditions; then, whether the amount of gas necessary to keep a given furnace at the required temperature can be obtained at a price comparable with that of coal. For heating steam boilers the gas answers well, and in many cases without any material change in the arrangement of the furnace. In Pittsburgh it has proved successful in the more important application to all the forms of iron manufacture, except in blast furnaces. For some time it was feared that the temperature necessary for casting steel could not be attained, but by making suitable changes in the furnaces the gas is now used with peculiar advantages in this industry. It is also used in the Siemens regenerative furnaces of the Edgar Thomson Steel Works. Among the prominent advantages of gas for use in iron works are: (1) The ease with which the fires can be controlled; the fire is steadier and therefore involves less wear upon the furnace. A furnace can be raised to a required temperature in considerably less time than with coal, and the direction of the flame can be changed easily; (2) the quantity of fuel is regulated by a valve instead of by shoveling in coal; (3) among the waste products there is neither ash nor the soot which affects the appearance if not the prosperity of every manufacturing town. As a substitute for coal, natural gas has become valuable in glass manufacture, particularly for flint glass, where coal smoke may not only color the glass but renders precautions necessary against reducing the lead. The use of gas allows glass manufacturers to dispense with the "teazer," whose duty consisted in securing an even temperature of the flame by constantly adding small quantities of coal. The use of natural gas in connection with the Siemens patents for improvements in glass furnaces has been discussed in an article read by Prof. B. Silliman, jr., at the Philadelphia meeting of the American Institute of Mining Engineers, September, 1884, to which the reader is referred.

As a source of light, natural gas has been used in many small towns, especially in the northern part of Pennsylvania and in New York. The fact that hydrocarbons of the ethylene series, which give the illuminating power to coal-gas, are seldom present in more than traces, and are usually absent altogether, would lead to the prediction that difficulty would be experienced in using the gas as a general substitute for coal gas. This seems to coincide with experience so far. Still there are records of natural gas giving an illuminating power of 16 to 22 candles, with burners using less than the normal volume of gas per hour; but the illuminating power seems to vary considerably, and is only up to the standard in the neighborhood of the wells or where the gas is still charged with vapor from the more volatile petroleum liquids. It may be quite possible, when more analyses have been made, to select wells for illuminating purposes which contain more than the average proportion of ethane and propane. It would be no difficult matter to enrich the gas with the products of the destructive distillation of naphtha, as in the Low process of making water gas. This would also give the gas a characteristic odor and remove the difficulty of detecting leaks, which have caused serious explosions in Pittsburgh. This leakage is particularly apt to occur with the present system of piping. The pressure in the mains is so great that it is practically impossible to prevent escape at the joints, even with the utmost care. This excessive pressure will soon be remedied by gas holders or suitable tank governors.

Carbons for electric lights have been made by heating natural gas to a very high temperature, the carbon being deposited in a very dense form; this is ground, pressed in molds with molasses, and baked in a muffle oven. Natural gas is also used in the manufacture of lampblack.

In regard to the probable duration of the supply, the history shows that some gas wells have been used profitably for many years; thus the flow of the wells at Fredonia, New York, and at East Liverpool and Cleveland, Ohio, has not diminished perceptibly. At other places wells have given out within a few weeks from their discovery; others have diminished slowly and failed entirely after a few years. Seven wells drilled in Butler county, Pennsylvania, for use in the iron works of Spang, Chalfant & Co., at Etna, near Pittsburgh, show the following records:

No. 1. In use nine years; still good.

No. 2. In use four years, still blowing, though with less force.
No. 3. Yield poor.
No. 4. Pressure fell from 1½ pounds to 0 pressure in one week.
No. 5. Failed after four years' use.
No. 6. In use six years; gradually failing.
No. 7. Failed after five years' use.

In many cases the failure of a well is not due to exhaustion, but to stoppage caused by solid particles collecting in the pores of the gas rock, or in the well itself. This solid matter is sometimes salt, or aluminum silicate, or in other cases solid members of the paraffine series, occurring with the oil and gas. By reaming and use of torpedoes, such wells are often restored. The force of many wells decreases rapidly on account of other gas wells drilled in the immediate neighborhood, which share the supply. Judging by the confidence displayed by capitalists, who are putting large sums of money into this new industry, it would seem that the two causes given above will account for the cases of known exhaustion sufficiently to warrant the belief that the supply of gas is assured for a length of time sufficient to give this variety of fuel an important industrial aspect.

IRON.

THE MANUFACTURE OF IRON AND STEEL IN THE UNITED STATES.

By James M. Swank,
Vice President of the American Iron and Steel Association.

Review of the growth of the American iron industry.—The iron industry of the United States has an interesting colonial history, having been established in nearly all the original thirteen colonies.

The first discovery of iron ore within the limits of the United States was made in North Carolina in 1585, exactly three hundred years ago, by the expedition fitted out by Sir Walter Raleigh, and commanded by Ralph Lane, which made in that year, on Roanoke island, the first attempt to plant an English settlement on the Atlantic coast.

The first attempt to manufacture iron in the American colonies dates from 1619, in which year the Virginia Company of London sent a number of skilled iron workers from England to Virginia to "set up three iron works" in the colony. These iron works were "set up" during the next three years, but before they had made any iron they were destroyed by the Indians in 1622, and no further attempt to manufacture iron in Virginia was made for many years.

In 1643 the first successful iron enterprise in the colonies was undertaken at Lynn, in the colony of Massachusetts Bay, by "The Company of Undertakers for the Iron Works," composed of eleven English gentlemen and a few enterprising colonists. This enterprise embraced a blast furnace and foundry, for producing castings and "sowe iron," and a forge for refining the "sowe iron" into "barr iron." The furnace was in operation in May, 1645, and the forge was in operation in September, 1648. These dates may be accepted as definitely determining, respectively, the first successful attempts in this country to make iron in a blast furnace and to produce bar iron in a refinery forge from the cast iron of the furnace. "A small iron pot, capable of containing about one quart," was the first article cast at the furnace. In 1844 this pot was in the possession of Mrs. Lewis, of Lynn, who was a lineal descendant of Thomas Hudson, the first owner of the lands on Saugus river, on which the iron works were built.

From the time of the establishment of the works at Lynn the colonial iron industry made steady although slow progress. The wants of the colonists for bar iron and castings were in large part supplied by colonial works from this time forward, but nails and other articles of iron, more advanced in manufacture than bar iron and castings, were still obtained chiefly from the mother country.

The furnaces supplied pots, kettles, andirons, stoves, clock weights, and similar articles which are now supplied by foundries, while the forges supplied wrought iron for horse shoes, wagon tires, harrow teeth, and some of the nails that were needed. Some of the forges refined the "sowe iron," or pig iron, of the furnaces, but the most of them made bar iron and other forms of wrought iron directly from the ore. The latter were Catalan forges of substantially the same type as the Catalan forge which had been in use in Europe since the beginning of the Christian era. As yet the rolling mill had not been invented, and all wrought iron was hammered into shape under trip-hammers.

The power used in blowing the furnaces and forges was usually supplied by water wheels which urged large leather bellows, formed like the ordinary blacksmith's bellows, or else upright wooden cylinders, or "tubs," worked with pistons. Another application of power was obtained by the use of the *trompe*, or water blast, an ingenious contrivance of Italian origin, which carried a small stream of water down a long perpendicular box, or hollow log, the water in its descent sucking in air through one or more apertures, which air passed out at the bottom with considerable force, while the water, through the intervention of a splatter board, flowed out in another direction. This water blast was much used in New Jersey and North Carolina, but it was not received with much favor in any of the other colonies. After the Revolution it was introduced into Tennessee, and in this and some other Southern States it may yet be found supplying the blast for a few primitive forges which make bar iron directly from the ore.

The fuel used in the colonial iron manufacture was exclusively charcoal. No other fuel was used in the manufacture of iron in this country down to 1827, when anthracite coal was first used at Phœnixville, Pennsylvania, in the puddling furnace. About 1840 we commenced to use anthracite and bituminous coal in the blast furnace.

In 1717 the colonies began to export to Great Britain small quantities of bar iron, and in 1728 the exportation of pig iron to Great Britain also commenced. Shipments of bar iron and pig iron to the mother country were continued almost yearly down to the Revolution. The exports in no one year exceeded 2,500 tons of bar iron, nor greatly exceeded 6,000 tons of pig iron. This export trade was wholly due to the scarcity of charcoal in Great Britain for the manufacture of iron in its coarser forms, the use of bituminous coal as a substitute for charcoal having but just commenced in that country and not being perfectly understood or generally favored.

For a hundred years after its settlement in 1620 Massachusetts was the chief seat of the iron industry in the colonies, but about the middle of the eighteenth century Pennsylvania became the leading iron-producing colony, and this distinction it has ever since maintained.

At the beginning of the Revolution nearly all the colonies were actively engaged in the production of iron. Georgia was the only colony that did not at this time produce even small quantities of iron. During the long struggle for independence the colonies produced iron in sufficient quantities to supply their armies with cannon, cannon balls, muskets, and camp kettles, and they manufactured also most of the steel that was required for swords and bayonets. All the steel made during the Revolution appears to have been blister steel. Henry Hollingsworth, of Elkton, in Cecil county, Maryland, was one of the manufacturers of muskets for the Continental army. Some of his bayonets were complained of as being too soft, "which he ascribed to the bad quality of the American steel with which they were pointed."

After the Revolution the manufacture of iron in the United States was extended from the Atlantic coast into the interior; but the aggregate production of the country did not greatly increase for many years, owing partly to the depressing effects of foreign competition, partly to the slow growth of the country in population, and partly to the really restricted use of iron in the days before the introduction of railroads. The railroad era in the United States had its beginning about 1830, but even after the new demand for iron for railroads had been created in our country the influence of foreign competition operated for many years to prevent an active development of our iron industry. This activity was reached at the beginning of our civil war in 1861, the Morrill tariff of that year and the war itself co-operating to create a greatly increased demand for iron of domestic manufacture, and contributing greatly to the establishment of the steel industry, which had previously existed under precarious and wholly embryonic conditions. A tremendous mechanical revolution in the production of steel has combined with other influences to increase a thousand-fold the production of American steel. The world has not yet learned to attach deserved importance to the inventions of Bessemer, Mushet, and Siemens, because it has become too much accustomed to thanklessly receive every new invention as a matter of course and to accept its fruits as a matter of right.

The statistical record.—There are no statistics of the production of iron in this country in the colonial period, nor of any other industry, nor of the population itself. Our forefathers were too intent upon getting for themselves homes, and too much employed in protecting these homes from imaginary or actual attacks by unfriendly Indians, to give attention to dry statistical details or economic problems. The first industrial statistics of the country date from 1814, in which year there was published "A statement of the arts and manufactures of the United States of America," as they existed in 1810, prepared by Tench Coxe, under the authority of Albert Gallatin, Secretary of the Treasury. From this statement the following table showing the condition of our iron industry in 1810 is compiled.

In the totals for the United States the values are believed to be correct, as they include returns from every State, but some of the quantities given are not strictly accurate, because some of the States did not report quantities although they reported values.

The figures for Pennsylvania are included in the figures for the country at large. The tons used are long tons, of 2,240 pounds.

The iron industry of the United States in 1810.

Establishments and products.	United States.	Pennsylvania.
Number of blast furnaces	153	44
Number of air furnaces		6
Tons of cast iron made (pig iron and castings)	53, 908	26, 878
Value of cast iron made	$2, 981, 277	$1, 301, 343
Number of bloomaries	135	4
Tons of iron made	2, 564	....
Value of iron made	$226, 034	$16, 000
Number of forges	330	78
Tons of bar iron, etc., made	24, 541	10, 969
Value of bar iron, etc., made	$2, 874, 063	$1, 156, 405
Number of trip hammers	316	50
Product of trip hammers in tons	600	....
Value of product of trip hammers	$327, 898	$73, 496
Rolling and slitting mills	34	18
Tons of rolled iron made	9, 280	4, 502
Product of slit iron in tons		98
Value of rolled and slit iron	$1, 215, 946	$606, 426
Number of naileries	410	175
Pounds of nails made	15. 727, 914	7, 270, 825
Value of nails made	$2, 478, 139	$760, 862

The growth of our iron and steel industries from 1810 until 1880 is shown by a comparison of the figures of the above table with the statistics of production of each leading branch of these industries in the census years 1870 and 1880, as follows, in short tons of 2,000 pounds:

The iron industry of the United States in the census years 1870 *and* 1880.

Iron and steel products.	1870.	1880.
	Short tons.	*Short tons.*
Pig iron and castings from furnaces	2, 052, 821	3, 781, 021
All products of iron-rolling mills	1, 441, 829	2, 353, 248
Bessemer steel finished products	19, 403	889, 896
Open-hearth steel finished products	....	93, 143
Crucible steel finished products	28, 069	70, 319
Blister and other steel	2, 285	4, 956
Products of forges and bloomaries	110, 808	72, 557
Total	3, 655, 215	7, 265, 140

The number of persons directly employed in 1880 in the production of iron and steel in this country was 140,978. This total does not include the labor employed in independent and often remote mining operations which supply our iron and steel industries with ore and coal and other raw materials. Nor does it include any considerable part of the labor employed in the transportation of raw materials from the sources of production to the places of consumption.

Rapid as was the growth of our iron and steel industries in the decade between 1870 and 1880, a yet more rapid and a really phenomenal growth took place in 1881 and 1882. In 1883, however, a reaction occurred, and in that year the production was less than in 1882, while in 1884 it was less than in 1883. The statistics of production obtained by the American Iron and Steel Association for the eleven calendar years from 1873 to 1884 are as follows, in short tons:

Production of iron and steel (stated in short tons) in the United States, 1873 *to* 1884 *inclusive.*

Products.	1873.	1874.	1875.	1876.	1877.	1878.
Pig iron	2, 868, 278	2, 689, 413	2, 266, 581	2, 093, 236	2, 314, 585	2, 577, 361
Spiegeleisen, included above	....	....	7, 832	6, 616	8, 845	10, 674
Rolled iron, including nails and iron rails	1, 837, 430	1, 694, 616	1, 599, 516	1, 509, 269	1, 476, 759	1, 555, 576
Rolled iron, including nails and excluding rails	1, 076, 368	1, 110, 147	1, 097, 867	1, 042, 101	1, 144, 219	1, 232, 686
Kegs of cut nails and spikes, included in rolled iron	4, 024, 704	4, 912, 180	4, 726, 881	4, 157, 814	4, 828, 918	4, 396. 130
Bessemer steel rails	129, 015	144, 944	290, 863	412, 461	432, 169	550, 398
Open-hearth steel rails	....	....	....	....	....	9, 397
Iron rails	761, 062	584, 469	501, 649	467, 168	332, 540	322, 890
Rails of all kinds	890, 077	729, 413	792, 512	879, 629	764, 709	882, 685
Crucible steel ingots	34, 786	36, 328	39. 401	39, 382	40, 430	42, 906
Open-hearth steel ingots	3, 500	7. 000	9, 050	21, 490	25, 031	36, 126
Bessemer steel ingots	170, 652	191, 933	375, 517	525, 996	560, 587	732, 226
Miscellaneous steel	13, 714	6, 353	12, 607	10, 306	11, 924	8, 556
Steel of all kinds	222, 652	241, 614	436, 575	597, 174	637, 972	819, 814
Blooms from ore and pig iron	62, 564	61, 670	49, 243	44, 628	47, 500	50, 045

Products.	1879.	1880.	1881.	1882.	1883.	1884.
Pig iron	3, 070, 875	4, 295, 414	4, 641, 564	5, 178, 122	5, 146, 972	4, 589, 613
Spiegeleisen, included above	13, 931	19, 603	21, 086	21, 963	24, 574	33, 893
Rolled iron, including nails and iron rails	2, 047, 484	2, 332, 068	2, 643, 927	2, 493, 831	2, 348, 874	1, 957, 307
Rolled iron, including nails and excluding rails	1, 627, 324	1, 838, 906	2, 155, 346	2, 265, 957	2, 283, 920	1, 931, 747
Kegs of cut nails and spikes, included in rolled iron	5, 011, 021	5, 370, 512	5, 794, 206	6, 147, 097	7, 762, 737	7, 581, 379
Bessemer steel rails	683, 964	954, 460	1, 330, 302	1, 438, 155	1, 286, 554	1, 116, 621
Open-hearth steel rails	9, 149	13, 615	25, 217	22, 765	9, 186	2, 670
Iron rails	420, 160	493, 762	488, 581	227, 874	64, 954	25, 560
Rails of all kinds	1, 113, 273	1, 461 837	1, 844, 100	1, 688, 794	1, 360, 694	1, 144, 851
Crucible steel ingots	56, 780	72, 424	89, 762	85, 089	80, 455	59, 662
Open-hearth steel ingots	56, 290	112, 953	146, 946	160. 542	133, 679	131, 617
Bessemer steel ingots	928, 972	1, 203, 173	1, 539, 157	1, 696. 450	1, 654, 627	1, 540, 595
Miscellaneous steel	5, 464	8, 465	3, 047	3, 014	5, 598	5, 111
Steel of all kinds	1, 047, 506	1, 397, 015	1, 778, 912	1, 945, 095	1, 874, 359	1, 736, 985
Blooms from ore and pig iron	62, 353	74, 589	84, 606	91, 293	74, 758	57, 005

Production of pig iron and Bessemer steel in 1884.—The production of pig iron in the United States in 1884 was 4,589,613 short tons, or 4,097,868 long tons. This was a decrease on the production of 1883 of 557,359 short tons, or 497,642 long tons, equivalent to 11 per cent. Notwithstanding this decrease, the production in 1884 was larger than that of any preceding year except 1881, 1882, and 1883. It was only 51,951 short tons below the production of 1881, and it was 294,199 short tons above the production of the "boom" year 1880. It was more than double the production of the centennial year 1876. If we regard only the quantity of pig iron produced in 1884, it cannot be said that the year's results were disappointing; they certainly were not; but if we consider the prices obtained for the year's product of pig iron, we find that they were very low, so low indeed that they were only slightly above the exceptionally low prices which prevailed in 1878. In that year the average monthly price of No. 1 anthracite foundry pig iron at Philadelphia ranged from $18.50 per long ton in January to $18.62 in December. In 1884 the price ranged from $20.50 in January to $18 in December.

The following table gives the yearly average prices of No. 1 anthracite foundry pig iron per long ton at Philadelphia since 1873, the yearly average being obtained from monthly averages.

Price of No. 1 *anthracite foundry pig iron,* 1873 *to* 1884 *inclusive.*

Years.	Average.	Years.	Average.
1873	$42.75	1879	$21.50
1874	30.25	1880	28.50
1875	25.50	1881	25.12
1876	22.25	1882	25.75
1877	18.88	1883	22.38
1878	17.62	1884	19.88

The lowest average monthly price of No. 1 anthracite foundry pig iron that has ever been reached was in November, 1878, when it was $16.50. In December, 1884, the price fell to $18.

The pig iron produced in this country in 1884 may be said to have been consumed during the year, as the quantity left in the hands of the manufacturers at the close of the year was very slightly in excess of that which they carried over from the preceding year. The stocks on hand at the close of 1883 amounted to 533,800 short tons, and at the close of 1884 they amounted to 593,000 short tons. The virtual restriction of the production of pig iron in 1884 to the demand for it was a wise determination of the manufacturers. A less cautious policy would have entailed widespread disaster.

Our imports of pig iron in 1884 were much smaller than they had been for many years, amounting to only 206,381 short tons. This addition to the production of the country also entered directly into consumption. Of the quantity imported a large part was spiegeleisen, for use in the manufacture of Bessemer and open-hearth steel, and another large part was Scotch pig iron. With the possible exception of a small quantity of spiegeleisen annually the country is now fully able to supply all its wants for pig iron of every description.

The following table shows the production of pig iron by States and Territories from 1880 to 1884. Twenty-six States and two Territories are included in the table, *Production of pig iron, by States and Territories,* 1880 *to* 1884 *inclusive.*

States and Territories.	1880.	1881.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
Maine	3, 578	4, 400	4, 100	4, 400	....
Vermont	1, 800	2, 796	1, 210	....	....
Massachusetts	19, 017	18, 318	10, 335	10, 760	4, 902
Connecticut	22, 583	28, 483	24, 342	19, 976	14, 174
New York	395, 361	359, 519	416, 156	331, 964	239, 486
New Jersey	170, 049	171, 672	176, 805	138, 773	82, 935
Pennsylvania	2, 083, 121	2, 190, 786	2, 449, 256	2, 638, 891	2, 385, 402
Maryland	61, 437	48, 756	54, 524	49, 153	27, 342
Virginia	29, 934	83, 711	87, 731	152, 907	157, 483
North Carolina	....	800	1, 150	....	435
Georgia	27, 321	37, 404	42, 440	45, 364	42, 655
Alabama	77, 190	98, 081	112, 765	172, 465	189, 664
Texas	2, 500	3, 000	1, 321	2, 381	5, 140
West Virginia	70, 338	66, 409	73, 220	88, 398	55, 241
Kentucky	57, 708	45, 973	66, 522	54, 629	45, 052
Tennessee	70, 873	87, 406	137, 602	133, 963	134, 597
Ohio	674, 207	710, 546	698, 900	679, 643	567, 113
Indiana	12, 500	7, 300	10, 000	9, 950	2, 568
Illinois	150, 556	251, 781	360, 407	237, 657	327, 568
Michigan	154, 424	187, 043	210, 195	173, 185	172, 834
Wisconsin	96, 842	102, 029	85, 859	51, 893	52, 815
Missouri	105, 555	109, 799	113, 644	103, 296	60, 043
Minnesota	3, 520	7, 442	8, 126	8, 000	....
Utah	....	....	57	....	....
Colorado	....	6, 396	23, 718	24, 680	15, 837
Oregon	5, 000	6, 100	6, 750	7, 000	3, 640
California	....	4, 414	987	5, 327	2, 157
Washington	....	1, 200	....	2, 317	540
Total	4, 295, 414	4, 641, 564	5, 178, 122	5, 146, 972	4, 589, 613

Pig iron has been manufactured with charcoal as fuel in the period covered by the table in all the States above mentioned, except New Jersey, Illinois, and Colorado, and in the two Territories mentioned. It has been made with bituminous coal and coke in sixteen States, namely, New York, Pennsylvania, Maryland, Virginia, Georgia, Alabama, West Virginia, Kentucky, Tennessee, Ohio, Indiana, Illinois, Michigan, Wisconsin, Missouri, and Colorado. It has been manufactured with anthracite coal in only five States, namely, Massachusetts, New York, New Jersey, Pennsylvania, and Maryland. In most of the States that use anthracite coal, particularly Pennsylvania, bituminous coke is largely used as a mixture with this fuel. Bearing this fact in mind the production of pig iron in the United States in the last six years can be classified as follows, according to the fuel used:

Classification of the pig-iron product according to fuel used (stated in short tons).

Fuel used.	1879.	1880.	1881.	1882.	1883.	1884.
Bituminous	1, 438, 978	1, 950, 205	2, 268, 264	2, 438, 078	2, 689, 650	2, 544, 742
Anthracite	1, 273, 024	1, 807, 651	1, 734, 462	2, 042, 138	1, 885, 596	1, 586, 453
Charcoal	358, 873	537, 558	638, 838	697, 906	571, 726	458, 418
Total	3, 070, 875	4, 295, 414	4, 641, 564	5, 178, 122	5, 146, 972	4, 589, 613

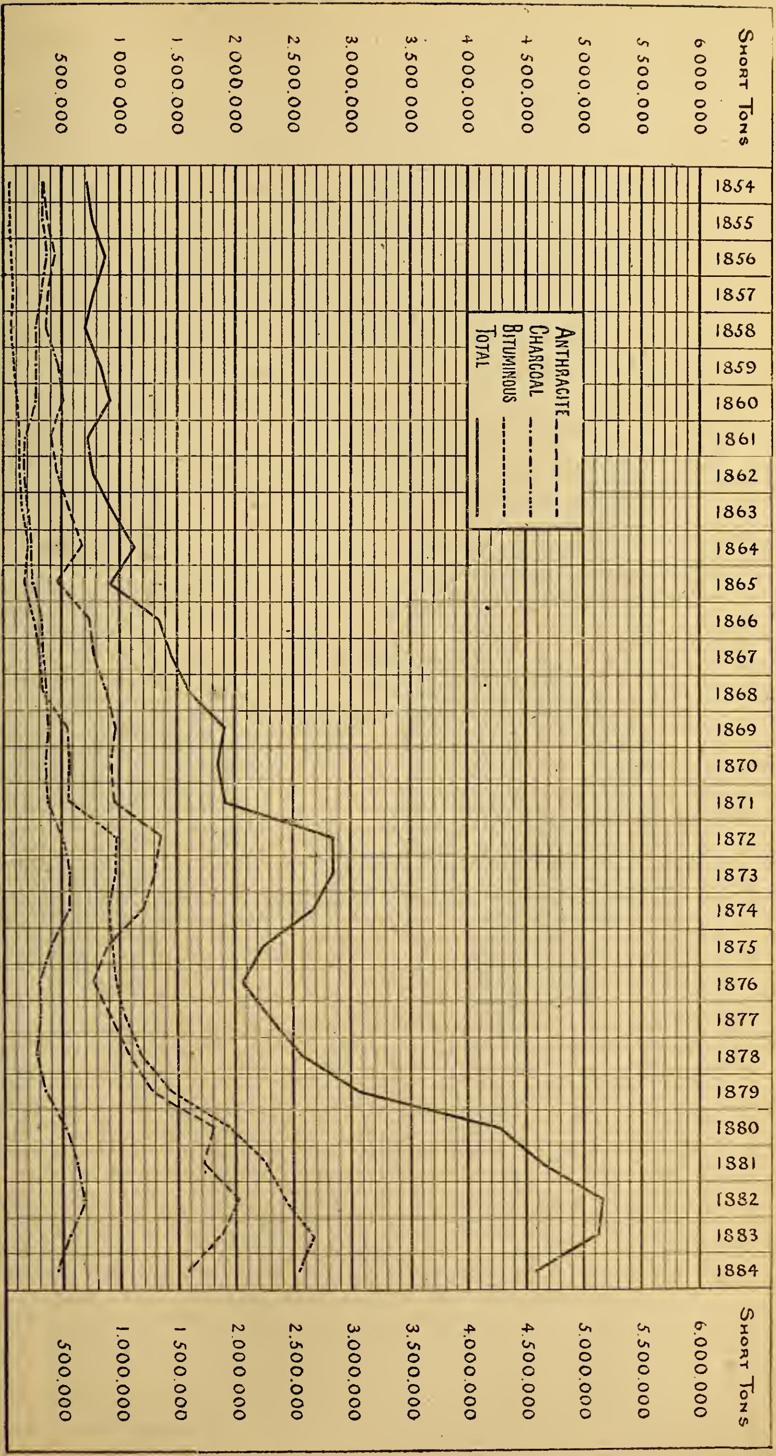

FIG. 1.—PRODUCTION OF PIG IRON IN THE UNITED STATES, 1854 TO 1884 INCLUSIVE.

The following table shows the production of spiegeleisen in the United States since 1875. The figures given are included in the statistics of pig iron production given above.

Production of spiegeleisen in the United States, 1875 *to* 1884 *inclusive.*

Years.	Short tons.	Years.	Short tons.
1875	7, 832	1880	19, 603
1876	6. 616	1881	21, 086
1877	8, 845	1882	21, 963
1878	10. 674	1883	24, 574
1879	13, 931	1884	33, 893

The following table shows the production of pig iron in the United States from 1810 to 1884, in tons of 2,240 pounds. The figures for the early periods have been carefully compiled from reliable sources of information and from the census reports; for 1870 and subsequent periods they have been taken from the records of the American Iron and Steel Association. The year 1882 was the year of highest production.

Production of pig iron in the United States since 1810.

Years.	Long tons.	Years.	Long tons.
1810	53, 908	1870	1, 665, 179
1820	20, 000	1880	3, 835. 191
1830	165, 000	1881	4, 144, 253
1840	286, 903	1882	4, 623, 323
1850	563, 755	1883	4, 595, 510
1860	987, 559	1884	4, 097, 868

The production of Bessemer-steel ingots in the United States in 1884 was 1,540,355 short tons, or 1,375,531 long tons. This was a decrease of 114,272 short tons, or 7 per cent. upon the production of 1883, a decrease so small in a year of general depression that it can only be explained by remembering that Bessemer steel is now largely used for many purposes for which rolled iron was formerly exclusively used. The production of 1884 was only 158,095 short tons below that of 1882, which was the year of greatest production of Bessemer steel in our history. The production of Bessemer-steel ingots from 1874 to 1884 by States has been as follows, in short tons:

Production of Bessemer-steel ingots in the United States, 1874 *to* 1884 *inclusive* (*stated in short tons*).

Years.	Pennsylvania.	Illinois.	Other States.	Total.
1874	85, 625	62, 492	43, 816	191, 933
1875	148, 374	136, 356	90, 787	375, 517
1876	258, 452	171, 963	95, 581	525. 996
1877	328, 599	111, 299	120, 689	560, 587
1878	426, 481	179, 500	126, 245	732, 226
1879	514. 165	250, 980	163, 827	928, 972
1880	643. 894	304. 614	254, 665	1, 203, 173
1881	844. 501	375, 763	318. 893	1, 539, 157
1882	933, 631	397, 436	365, 383	1, 696, 450
1883	1, 044, 396	273, 325	336, 906	1, 654, 627
1884	1, 031, 244	339, 068	170, 043	1, 540, 355

The total number of Bessemer-steel works in the United States at the beginning of 1885 was twenty, to which may be added several new works that are now in course of erection. The twenty completed works embrace forty-five converters. Several of these works were not in operation in 1884. Of the whole number of completed works, nine are located in Pennsylvania, one in New York, one in Massachusetts, two in Ohio, one in West Virginia, four in Illinois, one in Missouri, and one in Colorado. The new works in course of erection are located in West Virginia, Pennsylvania, Ohio, New York, New Jersey, and Illinois. Massachusetts and West Virginia made their first Bessemer steel in 1884.

The production of Bessemer-steel rails in this country in 1884 amounted to 1,116,041 short tons, a decrease of 170,513 tons on the production of 1,286,554 short tons in 1883, or over 13 per cent. It has already been stated that the production of Bessemer steel ingots in 1884 was only 7 per cent. less than in 1883. In 1883 the production of Bessemer-steel rails was 78 per cent. of the production of ingots, but in 1884 it was only 72 per cent.

The following table shows the annual production of Bessemer-steel rails in the United States since the commencement of their manufacture, together with the average annual price at which they have been sold at works in Pennsylvania, and the rates of duty imposed on foreign rails. The yearly price has been obtained by averaging the monthly prices.

Production and price of Bessemer-steel rails in the United States, 1867 *to* 1884 *inclusive.*

Years.	Long tons.	Price.	Duty.
1867	2,277	$166.00	45 per cent. ad valorem.
1868	6,451	158.50	
1869	8,616	132.25	
1870	30,357	106.75	
1871	34,152	102.50	$28 per ton to August 1, 1872; $25.20 to March 3, 1875; $28 from that date to July 1, 1883.
1872	83,991	112.00	
1873	115,192	120.50	
1874	129,414	94.25	
1875	259,699	68.75	
1876	368,269	59.25	
1877	385,865	45.50	
1878	491,427	42.25	
1879	610,682	48.25	
1880	852,196	67.50	
1881	1,187,770	61.13	
1882	1,284,067	48.50	
1883	1,148,709	37.75	From July 1, 1883, $17.
1884	996,465	30.75	

Raw materials and product in 1882, 1883, *and* 1884.—It is possible to ascertain very closely the quantity and value of raw materials which were consumed in the manufacture of iron in this country in 1882, 1883, and 1884. These are incorporated in the appended table. The value of the pig iron is averaged from trustworthy prices current. The value of the iron ore and limestone is averaged from special reports received from miners and consumers of iron ore and limestone in almost every section of the country. The "spot value of all iron and steel in the first stage of manufacture" covers all the pig iron produced, that part of the rolled iron which it is estimated is produced from old or scrap iron, and that part of the iron blooms which it is estimated is produced from old or scrap iron and iron ore, and excludes that part of the rolled iron and iron blooms which it is estimated is made from pig iron, and also excludes all steel, so as to avoid any duplication of values.

Summary of principal statistics of iron production in 1882, 1883, *and* 1884.

Details.	1882.	1883.	1884.
1. Pig iron made, tons of 2,240 pounds	4, 623, 323	4, 595, 510	4, 097, 868
2. Average spot value per ton at furnace	$23. 00	$20. 00	$18. 00
3. Total spot value pig iron at furnace	$106, 336, 429	$91, 910, 200	$73, 761, 624
4. Iron ore mined in United States, tons of 2,240 pounds	9, 000, 000	8, 400, 000	8, 200, 000
5. Iron ore (American) consumed, tons of 2,240 pounds	8, 700, 000	8, 800, 000	7, 718, 129
6. Average spot value per ton at mine	$3. 60	$3. 00	$2. 75
7. Total spot value American ore mined, at mine	$32, 400, 000	$24, 200, 000	$22, 550, 000
8. Total spot value American ore consumed, at mine	$31, 320, 000	$26, 400, 000	$21, 224, 854
9. Imported iron ore consumed, tons of 2,240 pounds	589, 655	490, 875	487, 820
10. Total iron ore consumed, tons of 2,240 pounds	9, 289, 655	8, 890, 875	8, 205, 949
11. Limestone consumed as flux, tons of 2,240 pounds	3, 850, 000	3, 814, 273	3, 401, 930
12. Average spot value limestone per ton at quarry	$0. 60	$0. 50	$0. 50
13. Total spot value limestone at quarry	$2, 310, 000	$1, 907. 136	$1, 700, 965
14. Anthracite consumed in iron smelting, tons of 2,240 pounds	3, 000, 000	2, 500, 000	1, 543, 688
15. Anthracite consumed in all iron and steel works, including furnaces, tons of 2,240 pounds	3, 800, 000	3, 200, 000	1, 973, 305
16. Bituminous coal consumed in iron smelting, tons of 2,240 pounds	1, 500, 000	750, 000	326, 986
17. Bituminous coal consumed in all iron and steel works, including furnaces, tons of 2,240 pounds	6, 600, 000	5, 550, 000	4, 226, 986
18. Coke consumed in iron smelting, tons of 2,240 pounds	3, 100, 000	3, 500, 000	3, 697, 275
19. Coke consumed in all iron and steel works, including furnaces, tons of 2.240 pounds	3, 350, 000	3, 750, 000	3, 833, 170
20. Charcoal consumed in iron smelting, bushels of 20 pounds	86, 500, 000	70, 322, 298	50, 577, 153
21. Charcoal consumed in all iron and steel works, including furnaces, bushels of 20 pounds	107, 000, 000	87, 000, 000	62, 110, 660
22. Total spot value of all iron and steel in first stage of manufacture, excluding all duplications	$171, 336, 429	$142, 000, 000	$107, 000, 000

The world's production of iron and steel.—The position of the United States among iron and steel producing countries at the present time is correctly indicated in the following table of the world's production of pig iron and steel of all kinds in 1883. This table places the world's production of pig iron in 1883 at 21,076,571 tons, and the world's production of steel in the same year at 6,277,690 tons. These figures represent respectively *the largest annual production of iron and steel that has ever been attained.* The percentage of pig iron produced by the United States was nearly 22, and its percentage of steel was 27. For comparison the latest coal statistics of the world have been added. They show the percentage of production by the United States to be 24. English tons of 2,240 pounds are used in giving the statistics of Great Britain, the United States, Russia, and "other countries," and metric tons of 2,204 pounds for all the continental countries of Europe except Russia.

The world's output of iron, steel, and coal.

Country.	Pig iron.		Steel.		Coal.	
	Year.	Tons.	Year.	Tons.	Year.	Tons.
Great Britain	1883	8, 490, 224	1883	2, 158, 880	1883	163, 737, 327
United States	1883	4, 595, 510	1883	1, 673, 534	1883	[a]96, 159, 719
Germany and Luxemburg	1883	3, 397, 588	1883	1, 066, 920	1883	70, 223, 456
France	1883	2, 067, 387	1883	509, 045	1883	21, 446, 199
Belgium	1883	770, 659	1883	220, 000	1883	18, 134, 880
Austria and Hungary	1883	655, 221	1883	271, 732	1882	15, 555, 292
Russia	1881	462, 042	1881	292, 360	1881	3, 437, 840
Sweden	1882	399, 001	1882	62, 203	1882	250, 000
Spain	1880	85, 939	1873	216	1880	847, 128
Italy	1883	53, 000	1876	2, 800	1882	220, 000
Other countries	1882	100, 000	1883	20, 000	1883	8, 000, 000
Total	......	21, 076, 571	......	6, 277, 690	......	398, 011, 841
Percentage of United States	......	22	......	27	......	24

[a] This amount differs slightly from that adopted as the "commercial product" on page 12 of this volume, but it is preferable to let the figures stand as compiled by Mr. Swank, inasmuch as the closeness of agreement between these independent estimates testifies to the value of both.—A. W., jr.

The production of pig iron and steel was less in 1884 than in 1883 in most of the leading iron and steel producing countries, including Great Britain and the United States, but the United States doubtless retained in that year the very high percentage of the total production which it achieved in 1883. Germany increased its production of iron and steel in 1884 over the production of 1883. The progress which Germany is now making in developing its iron and steel industries is largely the result of the introduction of the basic, or Thomas-Gilchrist, process for the manufacture of steel—a process that made possible the utilization of its phosphoriferous iron ores.

IRON ORES IN THE UNITED STATES.

By James M. Swank,

Vice President of the American Iron and Steel Association.

In the preparation of the following essay an attempt has been made to bring together in popular form the leading facts connected with our iron-ore resources and our domestic and foreign iron-ore supplies. The facts presented will afford a bird's-eye view of one of the great industries of our country, and of its relation to our extensive iron and steel industries and to the many other industries that are dependent upon them.

Imports of iron ore.—Previous to 1879 the quantity of iron ore imported into the United States was not recorded, but it did not amount to 100,000 tons in any one year. The quantity of iron ore imported from 1879 to 1884, both years included, was as follows, in tons of 2,240 pounds; the foreign value of the importations in these years is also given:

Imports of iron ore.

Years.	Long tons.	Value.
1879	284,141	$681,467
1880	493,408	1,436,809
1881	782,887	2,222,652
1882	589,655	1,640,564
1883	490,875	1,207,991
1884	487,820	1,133,678

The American Iron and Steel Association has ascertained the destination of 439,183 long tons of the 487,820 tons of iron ore imported in 1884. This information is presented in the following table:

Distribution of imported ores.

States and districts.	Long tons.
New York	9,562
New Jersey	1,918
Lehigh valley, Pennsylvania	147,891
Schuylkill valley, Pennsylvania	54,211
Upper Susquehanna valley, Pennsylvania	3,076
Lower Susquehanna valley, Pennsylvania	158,361
Allegheny county, Pennsylvania	20,288
Conemaugh valley and Youghiogheny valley, Pennsylvania	40,169
Charcoal furnaces, Pennsylvania	1,492
Maryland	600
Ohio	1,615
Total	439,183

These figures leave 48,637 tons unaccounted for, which were chiefly used in New York, New Jersey, Ohio, and Washington Territory. The figures presented in the table for Pennsylvania and Maryland are believed to be complete, or very nearly so. Of the 439,183 tons accounted for, 81,758 tons were used in the manufacture of pig iron for general purposes, while the remainder was used in the manufacture of Bessemer pig iron and spiegeleisen.

Our imports of iron ore are derived from many countries, but principally from Spain. The following table of imports of iron ore into the United States in the fiscal year which ended June 30, 1884, shows the sources of foreign supply for that year. Statistics for the calendar year 1884 are not attainable.

Sources of imported ores.

Countries.	Long tons.	Value.
Spain	374,943	$829,423
Italy	57,664	154,857
French possessions in Africa	56,448	109,920
Turkey in Asia	4,875	76,601
Canada	29,125	71,900
England	7,355	23,873
Greece	12,530	18,615
France	4,566	18,410
Portugal	6,299	13,942
Mexico	1	5
Total	553,806	1,317,546

The impulse that was given to the importation of iron ore in 1879, 1880, and 1881 was due partly to the high prices asked for Lake Superior ores, partly to a scarcity of iron ores on the Atlantic coast that were suitable for the manufacture of Bessemer pig iron, and partly to the revival in the American iron industry in these years, which created an extraordinary demand for iron ores for general as well as for special purposes. The first two of these influences have now largely disappeared, and the last one has entirely disappeared. Lake Superior prices have fallen, owing partly to the opening of new mines in that district, and new sources of supply of Bessemer ores have been developed in the East; but in the mean time American capitalists have made extensive investments in Cuban and Canadian iron-ore mines, the product of which is now being brought to this country for the manufacture of Bessemer pig iron, while increasing use of Spanish and Elba iron ores is being made by Eastern furnace owners in the manufacture of pig iron for the general market and for sale to steel manufacturers.

Much the larger part of the iron ore imported in 1882, 1883, and 1884 came from Bilbao and from Mediterranean ports, for use in the manufacture of Bessemer and other pig iron chiefly on or near the Atlantic coast, the inducements to import it being its richness, purity, and cheapness. The causes which influenced importations in 1879, 1880, and 1881 taught our people the value of foreign ores, and unless prevented by a high duty such foreign ores as have been used on the Atlantic coast will continue to be imported. The duty on iron ore was changed by the tariff which went into effect July 1, 1883, from 20 per cent. ad valorem to 75 cents per ton of 2,240 pounds. That foreign ore can be brought to this country at low prices is due in part, of course, to the very great cheapness of the labor that is employed in mining it, but largely also to the cheapness of ocean freights. The vessels which carry the ore are usually "ocean tramps," which carry grain, petroleum, lumber, and occasionally cotton to Europe, and the owners of which are glad to bring back ore at low rates rather than come in ballast. These vessels are all owned abroad.

The following table shows the quantities and values of iron ore imported into the various customs districts of the United States in the four calendar years 1881, 1882, 1883, and 1884. For this and the preceding table we are indebted to the courtesy of the Bureau of Statistics of the Treasury Department.

Customs districts receiving imported iron ores.

Districts.	1881.		1882.		1883.		1884.	
	Long tons.	Value.	Long tons.	Value.	Long tons.	Value.	Long tons.	Value.
Baltimore	375,798	$1,005,496	243,182	$654,629	236,998	$612,626	184,521	$357,136
Beaufort	....	....	....	....	1,473	4,243	1,749	5,005
Boston	716	2,867	1,664	3,322	2,470	5,277	2,865	7,765
Buffalo creek	2,492	7,320	273	755	....	....	....	....
Champlain	....	....	2	7	5	28	....	....
Cuyahoga	10,500	37,675	9,420	33,181	6,525	17,810	30,964	121,154
Detroit	617	1,646	48	98	....	....	10	27
Genesee	8,716	25,961	6,851	21,651	784	1,740	758	1,897
Huron	264	770	264	677	14	4	10	150
New York	196,419	641,344	145,909	421,776	36,800	94,236	29,401	82,995
Oswegatchie	3,418	10,650	905	2,783	942	2,866	....	....
Oswego	13,612	44,026	37,635	120,008	17,862	40,744	11,179	27,856
Perth Amboy	13,671	48,323	31,558	101,859	10,082	29,189	50,836	124,257
Philadelphia	155,564	394,952	111,944	279,818	170,420	386,386	169,507	388,900
Puget sound	1,100	1,622	....	....	3,521	7,084	2,012	4,024
Sandusky	....	....	....	....	....	....	2,177	5,387
Vermont	....	....	....	....	2,979	5,758	1,831	7,125
Total	782,887	2,222,652	589,655	1,640,564	490,875	1,207,991	487,820	1,133,678

The Juragua Iron Company, limited, an American company, has opened extensive mines of iron ore on the southeastern coast of Cuba, which it purchased early in 1883, and from which shipments to this country commenced in August, 1884. These shipments have since aggregated many thousand tons, and they promise to become in a short time a leading feature of our iron ore imports. Whether they will result in reducing the supply heretofore received from Spain is yet a matter of conjecture. The quantity of iron ore shipped in 1884 amounted to about 20,000 tons; the shipments in 1885 will probably reach 100,000 tons. The ores from these mines are used for Bessemer purposes. They are rich in iron and very low in phosphorus. The Juragua Iron Company, limited, is composed of the Bethlehem Iron Company, the Pennsylvania Steel Company, and Mr. Alfred Earnshaw.

Near Trenton, in the province of Ontario, in the Dominion of Canada, a company of American and Canadian capitalists, which was organized in 1883, has made extensive arrangements, involving a large expenditure of money, for mining iron ore from several mines which have been developed and from others which have been located. The ores of these mines are said to be well adapted to the manufacture of Bessemer steel. The shipping port is at Weller's bay, on Lake Ontario, 4 miles south of Trenton. The shipments to the United States during 1884 amounted to about 40,000 tons. An increase in the shipments for 1885 is expected. The principal promoters of the enterprise are Mr. S. J. Ritchie, of Tallmadge, Ohio; Hon. S. Burke, Hon. Henry B. Payne, and Mr. William Chisholm, of Cleveland, Ohio; Messrs. McMullen, of Trenton and Picton, Ontario, and Messrs. Coe, of Madoc, Ontario.

The following table shows the number of tons of iron ore imported during the last six years into each of the leading iron-manufacturing countries of the world:

Supplies of iron ore imported by various countries.

Years.	Great Britain.	France.	Germany.	Belgium.	United States.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1879	1, 083, 692	941, 812	380, 000	614, 534	284, 141
1880	2, 634, 401	1, 168, 215	607, 007	921, 784	493, 408
1881	2, 449, 277	1, 287, 870	615, 490	1, 169, 206	782, 887
1882	3, 282, 496	1, 425, 870	785, 360	1, 206, 717	589, 655
1883	3, 178, 310	1, 601, 217	800, 373	1, 612, 469	490, 875
1884	2, 728, 672	1, 412, 710	980, 442	1, 487, 748	487, 820

It will be seen from this table that the United States is the smallest importer of iron ore of all the countries mentioned. If we consider its prominent place among these countries, being second in the production of iron and steel, it is very much the smallest importer.

Production of iron ore in the United States in 1883 *and* 1884.—Full statistics of the production of iron ore in the United States are not obtained, and cannot be obtained, except in census years. The annual production of iron ore in the whole country may, however, be very accurately estimated. The average quantity of iron ore used in producing a ton of pig iron in the United States, in addition to the mill cinder that is used in some furnaces, is shown by the census of 1880 to be about 1.9 tons, while the production of pig iron is definitely ascertained from year to year by the American Iron and Steel Association, so that the quantity of iron ore produced in any year and used at our blast furnaces is approximately ascertained by multiplying the year's production of pig iron by 1.9 and deducting from the product the quantity of iron ore imported. By this method the following results are obtained for 1884: The pig iron produced, 4,097,868 long tons, multiplied by 1.9, gives 7,785,949 tons, from which, if we deduct 487,820 tons of iron ore imported, we have 7,298,129 tons as the home production of the year that was used at our blast furnaces. This country also annually produces in forges, directly from the ore, about 40,000 long tons of blooms and billets, representing about 120,000 tons of native ore. The largest and best of these forges are located in the Champlain district of New York, while others are found in Tennessee, North Carolina, Virginia, and Missouri. We also use some iron ore as fettling in the puddling furnaces of the rolling mills, and the quantity so used in 1884 is estimated, upon the basis of the census figures of 1880, to have amounted to about 300,000 tons, which, added to the domestic ore used in the blast furnaces and forges, gives 7,718,129 long tons as the probable production and consumption of domestic iron ore in 1884. This calculation takes no account of ore produced and not consumed.

That the figures above given of the production and consumption of iron ore in the United States in 1884 are correct is proved by statistics obtained by the American Iron and Steel Association. In response to a circular letter addressed to all the manufacturers of iron and steel in the country, and which was very generally answered, detailed information was furnished which indicates that the aggregate consumption of domestic iron ore in 1884 amounted to 7,639,581 long tons. This result is so close to the result reached by the method adopted in the preparation of this paper that it may safely be assumed that the quantity given by that method (7,718,129 tons) is correct and should stand.

As incidental to the present inquiry, it may be stated that, if we eliminate the mill cinder from the census statistics of 1880, and the probable amount of pig iron that was produced with it, it will appear that an average of 2.03 tons of iron ore was in that year required to produce a ton of pig iron. This is below the average in the leading iron-producing countries of Europe. Great Britain averages 2.4; Germany, 2.6; France, 2.6, and Belgium, 2.7.

The following statistics, showing the production of domestic iron ore in 1883 and 1884 in certain leading districts, have been obtained from reliable sources of information. As will be observed, the figures for 1884 embrace more than half the total estimated consumption of that year:

Production of leading iron-ore districts of the United States in 1883 *and* 1884.

Districts.	1883.	1884.
	Long tons.	*Long tons.*
Lake Superior mines of Michigan and Wisconsin	2, 352, 238	2, 455, 924
Vermilion Lake mines of Minnesota	Not opened.	62, 124
Missouri	295, 430	233, 225
Cornwall, Pennsylvania	363, 143	412, 320
Chateaugay mines, near Lake Champlain	194, 704	214, 394
Other Lake Champlain mines, including the Port Henry and Crown Point mines	305, 300	290, 500
New Jersey	521, 416	393, 710
Salisbury district, Connecticut	35, 000	25, 000
Hudson River Ore and Iron Company, New York	20, 000	90, 000
Total	4, 087, 281	4, 177, 197

In 1882 the Lake Superior region and the State of New Jersey reached respectively the largest production of iron ore in their history. In the former 2,947,392 long tons were produced, and in the latter the production was 932,762 tons.

The remainder of the domestic supply of iron ore in the two years mentioned, as well as in previous years, was obtained from mines located in all the States and Territories that produce pig iron, and located, too, in nearly every case in close proximity to the blast furnaces. There are very few States and Territories in the Union in which iron ore has not been discovered. The large number of "local mines" in so many States and Territories indicates not only the wide distribution of iron ore in the country, but also the existence of a disposition among the people of all sections to develop the various deposits as promptly as the wants of the country require. The iron-making instincts of our people are shown fully as much in their search for native iron ores and in the means they have used to develop them as in their readiness to adopt the best modern methods of manufacture. A less energetic people, for instance, would have been appalled by the difficulties which confronted the first shippers of iron ore from the Lake Superior region, and there are not to be found anywhere in the world to-day better or more expensive machinery and appliances for the mining of iron ore than are to be found in that district.

Spiegeleisen.—The latest illustration of the enterprise of our people in seeking at home for new sources of supply of iron ore of a quality or character that had not previously been discovered, or discovered in insufficient quantities, is seen in the search of the Bessemer-steel manufacturers for manganiferous iron ores in Michigan, Virginia, Georgia, Alabama, and Arkansas, a search which has resulted in a considerable increase during the past year in our production of spiegeleisen and ferro-manganese. The production amounted to 33,893 short tons, of which New Jersey produced 7,058 tons, Pennsylvania 26,509 tons, and Colorado 326 tons. The following table shows the production of these articles in the United States since 1875. In each year foreign as well as domestic ore was used, but in 1884 there was a marked diminution in the use of foreign ore.

Production of spiegeleisen and ferro-manganese in the United States, 1875 *to* 1884 *inclusive.*

Years.	Short tons.	Years.	Short tons.
1875	7, 832	1880	19, 603
1876	6, 616	1881	21, 086
1877	8, 845	1882	21, 963
1878	10, 674	1883	24, 574
1879	13, 931	1884	33, 893

New and old iron-ore fields in the United States.—Of the important deposits of iron ore that have been developed in this country and are still worked, the Salisbury district in western Connecticut was developed as early as 1731; the Schuylkill Valley mines in Pennsylvania were developed in 1716, and the Cornwall "ore hills," in the same State, about 1735; the magnetic iron ore mines in northern New Jersey were opened about 1710; the Sterling mines in Orange county, New York, in 1750, and the Champlain district, in the same State, about 1800; the Tennessee mines, the mines in Bath county, Kentucky, the Cranberry mines in North Carolina, and the Juniata Valley mines in Pennsylvania, near the close of the last century; the Hanging Rock region of Kentucky during the second decade of the present century, and the same region in Ohio during the third decade. The Iron Mountain and Pilot Knob region in Missouri was developed about 1845. The existence of iron ore on the southern shore of Lake Superior, the most celebrated and most productive iron-ore region in this country, was not even discovered until about 1830, and no attempt was made to develop it until 1845, just forty years ago. It is a noticeable fact, however, that, notwithstanding our early enterprise as iron manufacturers, some of the richest deposits of iron ore in this country were not developed, and in some instances were not discovered, until in very recent years. No attempt was made to develop some of these deposits until after the boom of 1879 and 1880, while the development of others was greatly stimulated by that event.

A notice of the location and characteristics of some of the older iron-ore fields above referred to and of all of the most recently developed deposits is demanded by the increasing public interest in the general question. Such illustrative chemical analyses as will be presented have in every instance been obtained from reliable sources.

1. The celebrated Marquette district, in Michigan, the most productive of all the iron-ore districts in the country, is mainly embraced in Marquette county, a small part of it extending northwest into Baraga county. Its principal ports of shipment for the ores that are not consumed in local furnaces are Marquette and Escanaba, the former on Lake Superior and the latter on Lake Michigan. Small quantities of ore are annually shipped from this district at L'Anse, on Lake Superior. There are at present several charcoal furnaces in the district. The great extent and great richness and purity of the hematite and magnetite iron ores of the Marquette district are too well known to require extended reference. The district is by far the most important iron-ore field in the United States.

Subjoined are fourteen analyses of the ores of the Republic mine, one of the most noted mines of the Marquette district, which we take from Mr. A. P. Swineford's "Mineral Resources of Lake Superior," printed in 1876. This mine is operated by the Republic Iron Company.

Analyses of ore from the Republic mine.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Metallic iron	65.11	67.75	68.01	69.88	69.24	71.82	68.40	68.23
Phosphorus	trace	.050	trace	.018	......	......	.080	.150
Silica	......	......	......	......	1.08	.84	.86	3.53
Lime	......	......	......	......	......	......	.82	......
Magnesia	......	......	......	......	......	......	.33	......

	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	Average.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Metallic iron	65.86	69.89	67.55	68.00	68.40	70.60	68.48
Phosphorus	.073	.060	.045	.050	......	......	.053
Silica	4.63	2.02	2.53	......	......	1.10	2.07
Lime	......	......	......	......	......	......	......
Magnesia	......	......	......	......	......	......	......

The iron ore of the Champion mine shows 67 per cent. of iron, 3 per cent. of silica, and 0.03 per cent. of phosphorus. Several analyses of West Republic ore that are before us show iron ranging from 66.483 to 68.583 per cent., and phosphorus ranging from 0.039 to 0.054 per cent.

Two analyses of the specular ore of the Lake Superior mine give the following results:

Analyses of ore from the Lake Superior mine.

	Per cent.	Per cent.
Metallic iron	64.831	65.680
Silica	3.600	3.700
Alumina	2.030	2.370
Lime	.550	.700
Magnesia	.600	.350
Phosphorus	.067	.095

2. The Menominee Range district is mainly situated in Menominee county, Michigan, the western part of it extending into Florence county, Wisconsin. This district ranks second in productiveness to the Marquette district. Both districts lie on the southern shore of Lake Superior.

The Menominee district owes its development mainly to the enterprise of the Menominee Mining Company, of Milwaukee. About 1876 this company obtained control of a large extent of country owned by the Lake Superior Ship Canal, Railway, and Iron Company, and by other parties, and at once commenced active operations. In 1877 10,405 tons were shipped, and thereafter shipments rapidly increased, both from the mines of this company and from mines opened by other capitalists. The Menominee Mining Company is still the largest shipper in the district, and the next largest is the Penn Iron Mining Company, a corporation which was organized in 1882, and which represents a large amount of Pennsylvania capital. The ore from this district is all shipped at Escanaba to ports below, except a very small quantity which is used at two local charcoal furnaces.

The ores of the Menominee district are generally red hematites, and partake of the same general characteristics as similar ores of the Marquette district, except that they are as a rule softer. They are found in large deposits. We subjoin analyses of the ores of some of the mines operated by the Penn Mining Company. These analyses were made by the Cambria Iron Company from ores used in its blast furnaces.

Analyses of ores of the Menominee district.

	Vulcan.	Cyclops.	Norway.	Quinnesec.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Metallic iron	63.930	60.470	58.940	67.05
Silica	6.860	3.380	12.270	4.80
Phosphorus	.013	.009	.016	.01

3. The statistics of the Marquette and Menominee iron-ore districts have usually been given together, but the districts are not contiguous. In a list of eighty-two mines in the two districts, which are cred-

ited in the Marquette *Mining Journal* with having produced iron ore in one or all of the last three years, fourteen are located in the Menominee district. The production of iron ore in 1884 in these two districts and by the isolated Colby mine, in Ontonagon county, also in Upper Michigan, was 2,455,924 long tons, of which the Menominee district produced 698,047 tons. In 1882, however, the two districts alone produced the exceptionally large quantity of 2,947,392 tons, and in that year the proportion of the Menominee district was 1,032,611 tons. The most productive mine in the whole Lake Superior region in 1883 and 1884 was the Chapin mine, in the Menominee district, which produced 265,830 tons in 1883 and 290,972 tons in 1884. The Lake Superior mine, in the Marquette district, has, however, produced a still larger annual product, its output in 1882 being 296,509 tons. This latter mine has been the most productive of all the mines in the Lake Superior region, the Cleveland, Jackson, and Republic mines, in the same district, coming next in the order mentioned.

Since 1856 the total production of iron ore on the southern shore of Lake Superior has amounted to 24,809,391 long tons. Most of the capital that has been invested in the development of the iron ores of this region has been supplied by New England, New York, Pennsylvania, and Ohio.

4. The Vermilion Lake iron district, in Saint Louis county, Minnesota, on the northern shore of Lake Superior, embraces several extensive mines that are opened or exposed, the most of them containing hard hematite ores of the same general characteristics as those found on the southern shore of the lake. The first shipment of iron ore from this district took place July 31, 1884, over the Duluth and Iron Range railroad, which connects Two Harbors, on Lake Superior, 25 miles northeast of Duluth, with the town of Tower, at the mines, the distance between the two places being 72 miles. This road, which is under the control of the Minnesota Iron Company, the owner of all the mines, is to be continued from Two Harbors to Duluth, where it will connect with the railroad system of the United States. At Two Harbors are extensive piers at which vessels will receive the ore, which it is expected will find its principal markets at ports on the lower lakes. The shipments in 1884, all to these ports, amounted to 62,124 tons. Shipments will be largely increased in 1885. Of the vast extent and uniformly good quality of the iron ores of this district there is no room for doubt, and the facilities for shipment are favorable. The policy of the company will be to ship only the best ores. All the Vermilion Lake ores are sufficiently low in phosphorus for Bessemer purposes, but they contain little or no manganese.

The existence of iron ores in this district was discovered by explorers about twenty years ago, but it was not until 1874 that any steps were taken to ascertain their extent or value, and not until 1883 that the building of the railroad was commenced. A few of the mines were opened in 1881 and 1882. The development of this district is in the hands of experienced capitalists, at the head of whom is Mr. Charlemagne Tower, of Philadelphia.

The following analyses, made by Messrs. Carnegie Brothers & Company, limited, of Pittsburgh, present a fair average of a large number which have been made of average samples from the Vermilion mines. The analyses here given are of ores from the mines which supplied the shipments in 1884.

Analyses of ore from Vermilion Lake mines.

	Breitung.	Stone.	Lee.
	Per cent.	*Per cent.*	*Per cent.*
Metallic iron	69.700	69.160	67.180
Manganese	....	trace	....
Phosphorus	.047	.053	.050
Sulphur	.007	.008	.025
Silica	.700	.700	2.150
Alumina	....	.400	1.230
Lime	.350	....	.450
Magnesia	trace	trace	.320

It is a fact of much interest that Minnesota, one of the prairie States, should promise to become a large producer of iron ore.

5. In the vicinity of Gogebic lake, in Ontonagon county, Michigan, on the southern shore of Lake Superior, and west of the Marquette and Menominee iron-ore districts, are extensive deposits of iron ore of the same general characteristics as the ores found in all the other Lake Superior districts. The existence of marketable iron ore in this district was discovered in 1880, but owing to the absence of railroad transportation no attempt was made until quite recently to develop any of the deposits, which will not be worked together, being controlled by various projectors and operators, principally under leases from the Lake Superior Ship Canal, Railway, and Iron Company. About twenty openings have been made, but down to the close of 1884 shipments of ore had been made from only the Colby mine, lying about 6 miles east of the Montreal river. It is claimed that the existence of extensive forests of hard wood in close proximity to the iron-ore deposits, and to calcareous marl as a fluxing material, justifies the erection of blast furnaces in the district. Analyses of numerous samples of marl found in the district show the deposits to consist of nearly pure carbonate of lime with but a trace of phosphorus.

The Milwaukee, Lake Shore and Western railway was completed to the Gogebic district in 1884, and during 1885 it is expected that it will be completed to Ashland, Wisconsin, on Lake Superior, where there is an excellent harbor and where expensive piers are being built, and from which it is expected that considerable shipments of iron ore to lower lake ports will be made before this year closes. It was over this road that the ore from the Colby mine was shipped by way of Milwaukee in 1884. The quantity shipped amounted to 1,022 long tons. It was received by Carnegie Brothers & Company, limited, of Pittsburgh, for use in their blast furnaces, and gave complete satisfaction. It contained a large percentage of manganese. From the Colby mine to Ashland the distance by railroad will be less than 50 miles, and from any of the mines in the vicinity of Gogebic lake to Ashland the distance will probably not exceed 75 miles.

In Ashland county, Wisconsin, just west of the Montreal river, which forms the boundary between Michigan and Wisconsin, are several promising iron-ore deposits which await development.

Analyses of the iron ores of the Gogebic district show that they are rich in metallic iron, very low in phosphorus, variable in silica, and free from sulphur. They are as a rule adapted to the manufacture of Bessemer pig iron. In a few mines manganese is also found in sufficient quantity in combination with iron to produce spiegeleisen. A few analyses of ore from the Colby mine are subjoined:

Analyses of ore from the Colby mine.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Iron and manganese	60.040	62.340	62.760	66.020	61.270
Metallic iron	48.630	55.490	57.140	65.100	52.700
Phosphorus	.083	.070	.071	.042	.075
Silica	6.080	2.680	3.690	8.840	1.820
Manganese	11.410	6.850	5.620	.920	8.570

Most of the analyses of the iron ores of this district that have been made show metallic iron ranging from 50 to 66 per cent.

6. There are four distinct iron ore fields in Missouri, known as the Iron Mountain, the Southeastern, the Southwest, and the Western districts. "The Iron Mountain region," to quote the words of Mr. W. B. Potter, "although much the smallest in area, is by far the most important, since it has produced, and still is capable of producing, more ore than all the other regions combined." This district is located in Iron and Saint François counties, from 80 to 90 miles south of Saint Louis. The principal deposits of the district are known as Iron Mountain and Pilot Knob. The former has been worked since 1845, and the latter since 1847. They have frequently been described. Iron Mountain alone has produced about 3,000,000 tons of ore; Pilot Knob has produced about 1,000,000 tons. In 1872 there were mined and shipped from Iron Mountain alone 269,480 tons. A large part of the production of Iron Mountain and Pilot Knob has been taken to Pittsburgh and other places on the Ohio river, but in recent years shipments have been mainly to nearer localities. Below are two analyses of Iron Mountain ore, taken

from a paper prepared by Mr. W. B. Potter in 1884, and published in the *Journal of the United States Association of Charcoal Ironworkers:*

Analyses of Iron Mountain ore.

	Surface ore.	Bluff ore.
	Per cent.	*Per cent.*
Peroxide of iron	95. 040	90. 610
Protoxide of iron	2. 570	2. 800
Silica	1. 570	3. 750
Alumina	. 790	2. 160
Lime	.170	. 480
Magnesia	. 140	. 320
Manganese	None.	Trace.
Sulphur	. 005	Trace.
Phosphoric acid	. 071	. 075
	100. 356	100. 195
Metallic iron	68. 530	65. 610
Phosphorus	. 031	. 033

The following analyses show the chemical composition of the iron ores of Pilot Knob:

Analyses of Pilot Knob ore.

	Per cent.	Per cent.
Peroxide of iron	84. 330	90. 870
Protoxide of iron	0. 150	1. 670
Silica	13. 270	5. 180
Alumina	2. 190	. 890
Lime	. 210	1. 760
Magnesia	. 140	. 130
Manganese	None.	None.
Sulphur	Trace.	. 078
Phosphoric acid	. 035	. 069
	100. 325	100. 647
Metallic iron	59. 150	64. 9100
Phosphorus	. 015	. 0031

A statement received from the Iron Mountain Company gives the average analysis of a series of samples of No. 1 ore from Iron Mountain as follows:

	Per cent.
Metallic iron	65. 5000
Silica	5. 7500
Sulphur	. 0160
Phosphorus	. 0405

In Crawford and Dent counties, Missouri, in the southwest section, just west of the Iron Mountain district, are numerous mines of rich ore operated by the Missouri Iron Company and by others. Several analyses of the ores of this section have been received from this company, which show metallic iron ranging in every case above 60 per cent., with a very low percentage of phosphorus, little or no sulphur, and variable silica. One of these analyses of the surface ore of Simmons mountain is as follows:

Analysis of Simmons Mountain ore.

	Per cent.
Peroxide of iron	98.140
Silicic acid	1.410
Alumina	.060
Lime	.240
Magnesia	.110
Phosphoric acid	.038
	99.998
Metallic iron	68.690
Phosphorus	.016

7. The immense Cornwall iron-ore deposit in Lebanon county, Pennsylvania, appears to be no nearer exhaustion to-day than when it was first opened, a hundred and fifty years ago. Detailed analyses of six samples of the ore of this mine are given below, "selected," as stated, "to give a general average of the quality of the ore." The mines supply a large number of local and neighboring furnaces. Pig iron made from this ore has been largely used as a mixture with other pig iron in the manufacture of Bessemer steel.

Analyses of Cornwall ore.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Magnetic oxide of iron	78.278	62.198	67.282	68.965	53.075	41.131
Sesquioxide of iron	....	....	Trace.	22.794	....	52.298
Oxide of copper	1.840	1.480	Trace.	.250	1.300	.030
Oxide of cobalt	.200	.095	.153	.067	.076	.105
Oxide of manganese	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Magnesia	1.286	2.695	1.867	1.228	3.193	1.369
Lime	1.000	1.110	1.210	1.403	1.510	1.111
Sulphuric acid	.039	.204	.105	.013	.187	....
Phosphoric acid	.072	.010	.006	.002	.003	.006
Silica	11.082	28.000	18.240	2.200	37.860	3.840
Copper pyrites	.352	1.818	.232	.084	.604	....
Iron pyrites	5.222	1.792	8.299	....	1.479	....
Water, etc	.629	.598	2.522	2.943	.603	2.107
Total	100.000	100.000	99.916	99.949	99.890	101.997
Metallic iron	59.229	46.422	52.666	65.952	39.380	64.992
Metallic copper	1.589	1.814	.080	.200	1.246	.024
Phosphorus	.032	.004	.002	.007	.001	.002
Sulphur	2.910	1.672	4.549	.045	1.076	....

8. The Salisbury iron region is properly confined to the town, or township, of this name in the northwestern portion of Litchfield county, Connecticut, but it is frequently referred to as embracing also the contiguous counties of Columbia and Dutchess, in New York, and Berkshire, in Massachusetts, the whole constituting a strip of country from

10 to 15 miles wide, in which may be found about twenty charcoal furnaces. The ores of this celebrated region are brown hematites, some of which are found in beds and others in veins. In the Salisbury region proper there are seven charcoal furnaces, which are supplied with ores from three mines, known as the Old Hill, Davis, and Chatfield. Iron has been manufactured in this part of Connecticut since 1734. Subjoined are complete analyses of the ores of the three mines mentioned, which still show no signs of exhaustion:

Analyses of ore from the Salisbury district.

	Davis.	Chatfield.	Old Hill.
	Per cent.	*Per cent.*	*Per cent.*
Sesquioxide of iron	75.720	78.136	73.51
Sesquioxide of manganese	1.376	.826	.96
Silica	7.580	6.630	10.48
Sulphur	.082	.048	.07
Phosphoric acid	.032	.501	.57
Lime, magnesia, alumina, water, etc	15.210	13.857	14.41
	100.000	99.998	100.00
Metallic iron	53.000	54.696	51.45
Metallic manganese	.958	.576	.67
Sulphur	.082	.048	.07
Phosphorus	.014	.219	.25

The pig iron produced from the Salisbury iron ores is in high repute for the manufacture of car wheels and of rolls for rolling mills, but it is also in demand for all purposes requiring great strength and tenacity. More than a century ago there were many forges in this district which produced bar iron of superior quality. The American navy has been supplied with many guns made from Salisbury iron. Only the ore of the Davis mine appears to be adapted to the manufacture of steel.

9. The State of New York is very rich in iron ore, the principal deposits of which lie along its eastern border, on both banks of the Hudson river and in the neighborhood of Lake Champlain. Much of the ore is magnetic, rich in iron, and low in phosphorus. In Clinton and Essex counties, in the Champlain district, iron has been made directly from the ore in numerous charcoal forges (more properly bloomaries) since the beginning of the century, and considerable quantities of pig iron have also been made in these and neighboring counties with anthracite coal and with charcoal. The annual production of iron ore in this district ranges from 500,000 to 600,000 tons. The quality of the iron made in this whole region is most excellent, and it enjoys a high reputation for various uses. As a rule the iron ores of this district are not adapted to the manufacture of any kind of steel, but some Bessemer pig iron is made in the district, and some mines produce ores the blooms and billets from which have been used in the manufacture of crucible steel. The following analyses are of the ore of one of the oldest iron-

ore companies in this section, the Port Henry Iron Ore Company, whose mines are located in Essex county:

Analyses of ore from the Port Henry mines.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Magnetic oxide of iron	88.323	88.772	76.608	81.381	85.559	84.623	92.78
Phosphoric acid	1.791	1.513	4.227	4.694	3.297	3.495	.71
Equivalent to—							
Metallic iron	63.958	64.287	55.475	58.935	61.957	61.279	67.19
Phosphorus	.782	.661	1.846	2.050	1.440	1.528	.31

10. The Chateaugay Ore and Iron Company, whose operations are on a large scale, was organized in 1881 (after the boom of 1879 and 1880), for the development of the Chateaugay mines, in the vicinity of Chateaugay lake, in Franklin county, west of Lake Champlain, the port of shipment being Plattsburgh, on the last named lake, with which the mines are connected by a railroad 35 miles long, owned by the company. The company owns about 75,000 acres of land. Since the commencement of operations in 1881 it has mined 752,101 tons of ore. The output was 102,626 tons in eight months of 1881, 240,377 tons in 1882, 194,704 tons in 1883, and 214,394 tons in 1884. To meet an extraordinary demand a production of 500,000 tons per annum is possible, the mines being fully equipped with powerful machinery and the ore being favorably situated. The mining plant employed by this company is one of the most extensive and complete in the country. In addition to its mining operations the company is a large producer of charcoal blooms, owning a number of forges in the neighborhood, and it also owns and operates one charcoal furnace at Plattsburgh. Much the larger portion of the ore produced by this company is, however, sold to furnace owners in New York and neighboring States, where it has been used in the manufacture of Bessemer steel and for other purposes. Subjoined is an analysis of Chateaugay ore, obtained from the company:

Analysis of Chateaugay ore.

	Per cent.
Peroxide of iron	47.380
Protoxide of iron	21.320
Protoxide of manganese	.210
Alumina	4.020
Lime	3.720
Magnesia	2.110
Phosphoric acid	.057
Sulphur	.084
Silica	20.890
	99.791
Metallic iron	49.750
Phosphorus	.025

11. In the immediate vicinity of New York City, and near to the Hudson river, are two celebrated iron-ore fields, one known as the mines of the Sterling Iron and Railway Company, which have been worked since 1750, and the other known as the Tilly Foster mine. The Sterling mines embrace about 22,000 acres in Orange and Rockland counties, and the Tilly Foster mine is in Putnam county. The Sterling ores are most used in the manufacture of foundry and mill pig iron, but the ore of some of the mines is a pure Bessemer ore. The reputation of the Sterling ores was made by the Long mine, which was discovered in 1750. The "Big mine" is the one that is now most worked. Its ores contain some phosphorus. The company itself operates two anthracite furnaces. The following are analyses of the ores of two of the Sterling mines:

Analyses of Sterling ore.

	Cook mine.	Scott mine.
	Per cent.	*Per cent.*
Metallic iron	64.24	65.47
Oxygen	24.48	24.93
Silica	7.45	4.92
Sulphur	None.	None.
Phosphorus	.184	.52
Alumina	1.13	.71
Lime	.72	1.59
Magnesia	.29	.56
Oxide of manganese	.17	.32
	98.664	99.02

The Tilly Foster ore is largely used by the Lackawanna Iron and Coal Company in the production of Bessemer pig iron, at Scranton, Pennsylvania, and it has also been used for the same purpose by the Bethlehem Iron Company. We subjoin an analysis of this ore which has been furnished by the Lackawanna Iron and Coal Company:

Analysis of Tilly Foster ore.

	Per cent.
Magnetic oxide of iron	67.41
Oxide of manganese	.30
Silica	11.75
Alumina	3.50
Lime	2.15
Magnesia	13.24
Sulphur	.08
Carbonic acid	2.30
Phosphoric acid	.05
	100.78
Metallic iron	48.82

Several other iron-ore deposits of similar character, which are apparently large but imperfectly developed, exist within a few miles of the Tilly Foster mine.

12. A new iron-ore field was developed in 1883 on the east side of the Hudson river, in Columbia county, by the Hudson River Ore and Iron Company, which has expended a large sum of money in prosecuting its enterprise. The ore of this district is described as a carbonate that is not greatly unlike the Cleveland ore in England, but much richer. When roasted it is adapted to the manufacture of Bessemer steel. The quantity of ore mined in 1884 by the company owning this property amounted to 90,000 tons. The deposits are very large. The following analyses of the ore after it had been roasted are taken from the *Iron Age:*

Analyses of roasted ores from Columbia county, New York.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Metallic iron	51.160	50.820
Silica	9.200	9.030
Sulphur	.550	.600
Phosphorus	.029	.031

Messrs. Crocker Brothers, of New York City, the agents of the Hudson River Ore and Iron Company, furnish the following more complete analysis of roasted ore:

Analysis of roasted ore from Columbia county, New York.

	Per cent.
Peroxide of iron	66.991
Protoxide of iron	3.584
Protosesquioxide of manganese	3.066
Alumina	2.637
Lime	3.720
Magnesia	7.125
Phosphoric acid	.087
Sulphuric acid	1.450
Silica	11.030
	99.690
Metallic iron	49.682
Phosphorus	.038
Sulphur	.580
Manganese	2.209

13. All the iron ores of New Jersey that are now mined are in the northern part of the State. They are chiefly magnetic. In the last century and during a considerable part of the present century bog ore was used in a number of charcoal furnaces in the southern part of the State. Most of the ores that are now mined are only suitable for forge or foundry purposes, but some are well adapted to the manufacture of Bessemer pig iron as they come from the mine, while others contain too much sulphur for this purpose and require to be roasted. These ores are also roasted when used for other purposes. We subjoin two analyses of magnetic ores, obtained in Sussex county, which are very low in

sulphur and are used at Franklin furnace in the manufacture of Bessemer pig iron:

Analyses of ores from Sussex county, New Jersey.

	Hill vein.	Furnace vein.
	Per cent.	*Per cent.*
Magnetic oxide of iron	69.50	65.40
Oxide of manganese	.46	4.13
Silica	18.27	1.05
Alumina	.27	.18
Lime	5.00	9.74
Magnesia	2.73	6.44
Sulphur	.10	.45
Carbonic acid	3.55	11.93
Phosphoric acid	.03	.05
Graphite	....	.78
	99.91	100.15
Metallic iron	50.32	47.35

A larger general average of the New Jersey magnetic ores would show a higher percentage of metallic iron and would be more favorable in other proportions for special purposes. For example, the ore of the Richard mine in Morris county, owned and operated by the Thomas Iron Company, averages 60 per cent. of metallic iron, and contains some phosphorus but no sulphur.

The present state of the iron-ore industry of New Jersey is described as follows by the State geologist, Prof. George H. Cook, in his annual report for 1884: "The low price of iron ore and the light demand for ore at almost any figure have caused a large shrinkage in the production and closed many of our mines. The large and increasing importations of iron ores from Spain and Africa also operate against our mines, since these rich and pure foreign ores can be put down at the furnaces near the seaboard at lower rates, per unit of metallic iron, than the New Jersey ores can be profitably mined and shipped to these same points. Besides, the adaptation of the former to the making of Bessemer iron enables them to compete successfully with our own Bessemer ores which are as yet scarcely developed. The discovery of new and productive mines along the Hudson, where ore can be obtained at a minimum of cost, also makes the competition for the Pennsylvania market sharp and telling against some of our mines where the expenses of mining are relatively larger, although our magnetic ores are richer."

14. So many varieties of iron ore are found in Ohio, and they are so widely distributed, that the State at first sight might be called rich in iron ore, and yet it annually makes more iron from Michigan ores than from the ores of its own mines. Pennsylvania, also, although celebrated as the leading iron-producing State, annually makes more iron from ores mined outside its borders than within them. A quarter of a century ago Professor Lesley wrote of Pennsylvania: "The reputation of this State for iron has resulted more from the energetic, persevering German use,

for a century of years, of what ores do exist, than from any extraordinary wealth of iron of which she can boast." In Ohio the ores of native origin are generally very lean, and too high in phosphorus to be serviceable in the manufacture of steel. Economy in the one case and necessity in the other combine to create a demand for Michigan ores, which are transported to ports on Lake Erie at comparatively slight cost, meeting the fuel to smelt them at many places in Ohio, even as far south as the Ohio river. Michigan ores are taken in large quantities to the Shenango valley and to Allegheny, Cambria, and other counties in western Pennsylvania. Spanish and other foreign ores also find their way to this part of the State, and are still more largely consumed in the eastern part, in both sections meeting the best of mineral fuel. Michigan and foreign ores are used in Pennsylvania because of their fitness as a mixture with native ores and their comparative cheapness, and also because of the leanness of so many of the native ores and of the phosphorus that most of them contain.

Analyses of the ores of Ohio and Pennsylvania are unnecessary, their character being well known. It must be added, however, that Ohio is a large manufacturer of rolled iron and of the best qualities of foundry iron, produced from its Hanging Rock, blackband, and other native ores, and that the bar, plate, and sheet iron of Pennsylvania and its foundry iron, made exclusively from native ores, are unexcelled anywhere. In both States charcoal is still used as fuel in many furnaces.

15. Indiana and Illinois produce so little iron ore that details may properly be omitted. The same observation may be made of all the New England States except Connecticut, which has already been noticed. Illinois is, however, one of the most prominent iron and steel producing States in the Union, but the ores it uses are mostly drawn from Lake Superior and Missouri, and the fuel for its blast furnaces is obtained mainly from the Connellsville region of Pennsylvania.

16. Delaware does not now manufacture pig iron, although it contains some small deposits of very good ores for general purposes. Maryland is not a large manufacturer of pig iron, but the pig iron that it makes from its own ores is noted for its great strength, and also for its adaptability to the manufacture of car wheels. Some foreign ores are imported into this State for use as a mixture with native ores. Very little Bessemer pig iron has been made in Maryland.

17. Iron ores are found in most parts of Virginia, and they are usually of good quality, although very few are perfectly adapted to the manufacture of Bessemer steel, and these have thus far been found mainly in small pockets. It is possible that large bodies of ore may yet be developed along the lines of the Norfolk and Western and the Shenandoah Valley railroads, and elsewhere, which will be suitable for the manufacture of steel. In southwestern Virginia pig iron of a very superior quality for the manufacture of car wheels has long been made in

charcoal furnaces. In other parts of Virginia pig iron of excellent quality is made in a few charcoal furnaces and in several new and large coke furnaces, and this iron is finding a market for general purposes as far north as New England.

Near Crimora station, in Augusta county, Virginia, on the Shenandoah Valley railroad, is a large deposit of manganese ore (described more fully under the head of Manganese, in this report), which has been worked for several years and which has contributed during the past year a considerable quantity of ore for the manufacture of spiegeleisen and ferro-manganese, in Pennsylvania. An analysis of this ore gives 57.291 per cent. of metallic manganese, 0.373 of metallic iron, and 0.075 of phosphorus. There are other promising deposits of manganese ore in this State.

In West Virginia a great variety of iron ores is also found, which are smelted with both coke and charcoal, but few if any of these have been used in the manufacture of steel. The Bessemer steel that is now manufactured at Wheeling is made from pig iron smelted from Lake Superior and Missouri ores. The State is more noted for its coal deposits and for the large quantities of nails it manufactures than for its iron ores.

18. An extensive deposit of magnetic iron ore is found on the western slope of Iron mountain, in Mitchell county, North Carolina, about 3 miles from the Tennessee line, which is known as the Cranberry "ore bank." This deposit has been worked in a small way for a hundred years, the ore being converted into bar iron in neighboring bloomaries; but recently the Cranberry Iron Company has made preparations to ship the ore to other sections of the country, and it has also built a small charcoal furnace at the mines. The distance from the mines to places of consumption is, however, so great that up to the present time but little ore has been shipped, although its superior adaptability to the manufacture of steel is everywhere acknowledged. It is practically free from sulphur and phosphorus. The following analyses of Cranberry ores are taken from Mr. P. M. Hale's work on "The Coal and Iron Counties of North Carolina:"

Analyses of Cranberry ores.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Magnetic oxide of iron	94.37	91.45	85.59	80.77	91.89
Oxide of manganese	.26	.06	.24	1.42	.32
Alumina	.42	.77	.11	.52	1.03
Lime	.43	1.01	.72	....	1.06
Magnesia	.36	.53	.33	....	.23
Water	....	.44	1.53	8.21	1.15
Silica, pyroxene, etc	4.16	5.74	11.48	9.08	4.02
Sulphur	....	....	....	....	.25
Phosphoric acid	....	....	....	....	Trace.
	100.00	100.00	100.00	100.00	99.95
Metallic iron	68.34	66.22	61.98	58.49	66.53

North Carolina has many other deposits of magnetic and hematite ores, which have been fitfully worked in a small way for more than a century, but none of these deposits, not even the Cranberry ore bank, will compare in extent with the immense deposits of Lake Superior, the Iron mountain and Pilot Knob in Missouri, and the Cornwall ore hills in Pennsylvania. The coal deposits of North Carolina are as yet practically undeveloped.

19. The iron ores of Kentucky, Tennessee, Alabama, and Georgia embrace most known varieties, and they are certainly found in very large quantities, and are widely distributed. They have been worked for many years, some of them for a hundred years, and much of the iron made from them has enjoyed a very high reputation for strength and toughness. Until in recent years charcoal was exclusively used as fuel, but now coke is largely used, chiefly in new and modern furnaces. Chattanooga and Birmingham are now as well known iron centers as Pittsburgh, Youngstown, Johnstown, or other places in the North. Southern pig iron is shipped to Philadelphia, to New York City, and to New England markets and sold at a profit. The impetus recently given to the iron industry of this region is largely due to investments of Northern capital. The four Southern States mentioned do not as a group produce any appreciable quantity of steel, and for the reason that very few ores suitable for the manufacture of steel have been discovered. Even in the vicinity of Birmingham, where there are a dozen furnaces, no attempt has yet been made to manufacture Bessemer pig iron, because suitable ores are not within reach. Some ores, it is true, are sufficiently low in phosphorus, but they are practically unfitted for the manufacture of steel because of the very great irregularity in the occurrence of this obnoxious element. Ore has been taken from some hematite veins in Alabama that was almost free from phosphorus, but 20 yards distant in the same vein one-half of 1 per cent. of phosphorus has been found. In Georgia and Alabama several small mines of manganiferous iron ore suitable for the manufacture of spiegeleisen have been opened and their product is now being utilized. Representative analyses of Alabama ores are annexed:

Analyses of Alabama ores.

	Magnetic.	Red hematite.		
		No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Oxide of iron	66.05	63.87	84.58	80.64
Oxide of manganese	10.25	.23	.40	.40
Alumina	6.98	.29	3.14	.50
Lime	....	.18	5.06	.12
Magnesia	....	.43	1.23	.33
Silica	13.00	33.22	5.54	16.80
Phosphoric acid	1.08	1.16	.07	.88
	97.36	99.38	100.02	99.67
Metallic iron	47.83	44.71	61.240	56.45
Phosphorus	.147	.50	.030	.34

The iron ores of Tennessee have long been celebrated. Bar iron was made in its Catalan forges a hundred years ago, and fifty years ago iron was made in considerable quantities in this State and shipped to Pittsburgh in the form of blooms. Much of the capital then used in developing its iron-making resources was supplied by Pennsylvania ironmasters. In the manufacture of car wheels and best refined bar iron the iron ores of Tennessee have no superior. As one result of the extension of the railroad system of the State it is supposed that larger deposits of iron ore than have ever been worked within its borders will soon be developed. The iron ores of this State exist in such great variety that any analyses we might give of them in our limited space would represent only a small part of them.

The most important iron-making district in Kentucky is the Hanging Rock district, and yet this district now draws its principal supply of ore from Bath county, in the same State, but outside of the district. Considerable quantities of ore from Bath county are annually sent to Ashland, Kentucky, and also to Ironton and Columbus, Ohio. An average analysis of the ores of Bath county is as follows:

Analysis of ore from Bath county, Kentucky.

	Per cent.
Peroxide of iron	76.070
Alumina	2.590
Lime	.130
Magnesia	.281
Silica	8.180
Phosphoric acid	1.000
Water	12.310
	100.561
Metallic iron	48.00
Manganese	.48
Phosphorus	.70

The only reason why the Hanging Rock region draws a large part of its supply of ore from Bath county appears to be the greater richness of this ore as compared with Hanging Rock ores. The latter average about 32 per cent. of metallic iron, whereas the Bath county ore averages, as has just been shown, about 48 per cent. The requirements of modern furnace practice and the severity of competition now militate greatly in all sections against the use of lean ores. The Bath county ores produce a soft, fluid iron, very suitable for foundry purposes. The first blast furnace in Kentucky was built in Bath county in 1791. The iron ores of other sections of Kentucky produce excellent iron for rolling-mill purposes.

20. Outside of Missouri none of the States and Territories lying west of the Mississippi river have developed an iron industry of especially significant proportions. Colorado and California have made the most progress in this direction, but even their achievements have fallen very

far short of the results accomplished by many of the older States. Nearly all of the States and Territories west of the Mississippi contain iron ore, but this part of our country is too vast and too new, and transportation within its limits is too restricted, to have either called for or permitted much attention to the manufacture of iron. In the light of present developments we may safely conclude that the iron industry west of the Mississippi and outside of Missouri will be of slow growth. The most recent and valuable discovery of iron ore in the section of country under consideration has been made in Arkansas, where ore of a character suitable for the manufacture of spiegeleisen has been found in Independence county in large quantities, and is now being used by Carnegie Brothers & Company, limited, and the Cambria Iron Company.

Summary.—The foregoing bird's-eye view of the iron-ore resources of our country establishes a number of important facts. It brings freshly to mind the remoteness from points of ultimate consumption of the great Lake Superior iron-ore fields, where quantity and quality of ore are found in combinations unequaled in any other section. It shows that, widely as iron ores are distributed in this country, such of these ores as are suitable for the manufacture of steel are confined to comparatively limited areas, but that they are in abundant supply. It shows that some of the most important iron-ore deposits in the country have been developed since the boom of 1879 and 1880. It shows that foreign ores, obtained in Spain, Italy, and other countries, are yearly imported into many States to be used either alone or as a mixture with native ores, and that the reasons for this importation are, first, their excellence for special purposes, particularly the manufacture of Bessemer pig iron and spiegeleisen, and, second, their cheapness as compared with native ores that must be transported long distances by rail. We do not, however, import annually one-fifth as much foreign ore as Great Britain, nor one-half as much as France or Belgium, and but little more than one-half as much as Germany. As has been shown, our imports of iron ore in 1884 amounted to only one-sixteenth of the total quantity of domestic iron ore consumed in that year.

If the question were asked whether this country could, if required, supply from within its own borders all the iron ore needed in every branch of its iron and steel industries, including the manufacture of the finer kinds of crucible steel, the answer might unhesitatingly be made in the affirmative. We can make as good iron for crucible steel as the Swedes do if we would only be as painstaking as they are. We have ores in great abundance for the manufacture of Bessemer steel by the original or acid process, which is the only process for the manufacture of this kind of steel that now exists in this country, if we except one unsatisfactory experiment that has recently been made with the Thomas-Gilchrist or basic process, and one establishment for the manufacture of steel by the Clapp-Griffiths process. These ores are, however, not readily accessible to all the Bessemer establishments of the country. We have discovered ores for the manufacture of spiegeleisen and ferro-manganese that would place our steel industry on a self-sustaining basis if our foreign supply of these products should be interrupted. We would be better off in this particular than Great Britain, which is practically without manganiferous iron-ore deposits. Manganese itself we export to that country. The firm of Carnegie Brothers & Company, limited, of Pittsburgh, uses only domestic ore in the manufacture of its high grade ferro-manganese.

As steel has rapidly come into use in late years as a substitute for iron, not only for rails but for other purposes, it is a fact of some interest, to which, we believe, public attention has not heretofore been called, that pig iron suitable for the manufacture of Bessemer steel by the process that is now in use in this country has never been made in any part of the country south of the Potomac or south of Wheeling. Southern ores, with rare exceptions, are too high in phosphorus for the purpose mentioned. If the South should engage in the manufacture of Bessemer steel to a greater extent than it has yet done at Wheeling it would probably employ the Thomas-Gilchrist process, which requires that pig iron should be high in phosphorus that the work of elimination in the converter may be completely successful; or it would employ the Clapp-Griffiths process, which is said to permit the presence in the steel itself of a large percentage of phosphorus without detriment to its quality, a result which is only rendered possible by the rigorous exclusion of silicon.

IRON IN THE ROCKY MOUNTAIN DIVISION.

By F. F. Chisolm.

Colorado.—The iron-ore mines of Colorado which have been developed are owned by the Colorado Coal and Iron Company. Other deposits are known, but they have not yet been opened, and the character of their ore, except in the case of the Cebolla mines, is probably inferior. The principal iron ore mines owned by the Colorado Coal and Iron Company are the Placer, Grape Creek, Hot Springs, and South Arkansas.

The Placer mine is on the Trinchera estate and on the west slope of the Culebra range, in Costilla county. The mine has been quite extensively opened, but has been abandoned because the ore became too mixed to allow of assorting at the mine. Tests of other mines in the neighborhood proved that the ore was of the same character. In all 14,775 tons of iron ore were produced from this mine.

The Grape Creek property lies at the head of Pine gulch, in the Wet mountains of Custer county. The ore is a refractory magnetite carrying from 13 to 15 per cent. of titanic acid. It occurs in diorite in irregular short veins of no great depth. The development is slight, and the ore is simply used for fettling the company's puddling furnace. Up to May 1, 1884, 921 tons of ore had been extracted, while a contract for 450 tons more had been let.

The Hot Springs mines, six in number, lie on the western slope of the Sangre de Cristo range. The ore is a porous brown hematite of pure character, occurring in isolated masses on the slopes of the sharply rising foothills. There are no regular or continuous ore bodies. The ore is mined by open cuts. The ore contains, according to analyses made for the company:

	Per cent.	
Iron	53.37 to	57.60
Silica	7.90	5.60
Sulphur	0.20	0.005
Phosphorus	0.034	0.014
Lime	0.35	
Alumina	0.70	0.74
Magnesia	.50	.40
Manganese	1.05	1.59

Up to May 1, 1884, 76,194 tons of ore had been produced, of which 11,179 tons were mined in 1884. The ore exposed is estimated by Mr. C. M. Rolker to be certainly 25,000 tons in the developed properties, while in the others there is perhaps from 25,000 to 50,000 tons more. The amount of ore on the dumps May 1, 1884, was 8,525 tons. The deepest shaft on these properties is 294 feet.

The South Arkansas mine is situated about 19 miles from Salida, in Chaffee county. It includes six mining claims and embraces some 700 acres of ground. This is considered to be the most valuable property owned by the company. The ore body is opened by a tunnel 756 feet long and an incline of 290 feet. The lode dips 43°, and at the outcrop its full width is probably 30 feet, with 8 feet of good and 5 feet of mixed ore. From the developments Mr. Rolker estimates the amount of ore in sight at 179,600, or, conditional upon certain further developments, 236,000 tons. Officers of the company estimate the exposed ore at a much greater figure. There were piled in the mine April 1, 1884, about 8,000 tons of good ore. Analysis of the outcrop showed:

	Per cent.	
Metallic iron	31 to	48
Silica	30	38

Analysis of car sample of raw ore taken as shipped.

	Per cent.
Metallic iron	51.30
Silica	12.40
Sulphur	1.42

Analysis of an average of a large lot of roasted ore.

	Per cent.
Metallic iron	50.44
Silica	14.97
Sulphur	.75
Lime	5.41
Alumina	3.24
Magnesia	4.09
Manganese	.22

A sample of magnetite yielded:

	Per cent.
Metallic iron	59.00
Silica	7.10
Sulphur	1.26

Up to May 1, 1884, the mine had yielded 45,483 tons of ore, of which 6,873 tons were mined in 1884. Some of the ores from this region contain quite large quantities of iron pyrites and must be roasted.

Beside the mines owned by the Colorado Coal and Iron Company, iron ore is known to occur in quite a large number of localities, but nowhere in great quantity except on Cebolla creek, in Gunnison county, and near Gunnison City. The ore here is said to be a good magnetite, and the following analysis is furnished:

	Per cent.
Magnetic oxide of iron	56.63
Peroxide of iron	38.66
Alumina	0.48
Lime	1.02
Magnesia	0.37
Silica	1.87
Phosphorus	0.0084
Sulphur	0.012
	99.0504

This ore contains 68.06 per cent. of metallic iron. The deposits here are quite large, and a company was formed for the purpose of working them and for the erection of foundries and furnaces, but little has been done beyond the survey of the ground for the location of the works.

Beds of iron ore of limited extent are also found in the Laramie rocks near the coal seams at Langford, Morrison, Como, and elsewhere. Mr. Marshall, owner of the Marshall coal mine, first smelted iron ore in Colorado with a small furnace at Langford. Before 1873 he produced in a two months' run some 250 tons of pig iron. It was found that it required 5,000 pounds of ore to make one ton of iron. The ore used was mined in the immediate neighborhood of the coal bank, but after a fair trial the supply proved insufficient, and the furnace was abandoned.

The red hematite ore found near Morrison was formerly manufactured into paint, but the mill has been closed for some time.

The Colorado Coal and Iron Company own at South Pueblo iron and steel works, rolling mills, and nail factory. The plant at the steel works consists of one blast furnace 65 feet high, with 15-foot bosh, and three Siemens hot stoves of the usual construction 56 feet high and 15 feet 6 inches in diameter, and blowing engine and necessary boilers. Furnace No. 2 is not yet completed. The converter house has two cupola furnaces 8 feet in diameter, two 5-ton converters, with necessary cranes, heaters, pumps, and blowing engines. The boiler house contains thirty boilers. In the blooming mill and rail mill there are three Siemens regenerative blooming furnaces with hydraulic drawing and charging apparatus, a 35-inch bloom train, 42 by 48-inch engine, and blooming-mill table; also power rolls, shears, one reheating furnace, with power-drawing apparatus and conveying buggy to rail rolls. The rail roll is a three-high 23-inch train, with necessary power rollers, hot saws in gangs of three, hot straightening plate, cold straightening machine, and slotting and drilling-machine. The puddling mill and nail factory are supplied with two "double double" and one "single double" Siemens puddling furnaces, a three-high 20-inch muck train with Burden squeezer attached, shears, one Siemens heating furnace, and one scrap-furnace, one 22-inch nail-plate train and shears, twenty-seven nail-cutting machines, all of improved pattern, and the necessary apparatus for blueing, tumbling, and annealing. The works are supplied with twenty-four Siemens gas producers, which supply gas for all the heating and puddling furnaces throughout the works. The works have their own foundry with two cupolas, complete machine, pattern, carpenter, and blacksmith shops, planing mill, and brick yard, and are lighted by Brush lights. In addition to this plant, the rolling mill formerly in Denver has been moved to Pueblo, adding to the plant there two heating furnaces for 16-inch bar train, one heating furnace for 10-inch train, four boilers, and two engines, one 24 by 60-inch and the other 16 by 22-inch, and other necessary machinery. This change was made simply for the sake of economy in handling, and the rolling mill in Denver will be abandoned for the present.

The production of iron ore and iron and steel by the Colorado Coal and Iron Company has been as follows:

Iron ore mined by the Colorado Coal and Iron Company.

Mines.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*
South Arkansas	14,202	19,645	10,483
Hot Springs	29,190	25,939	12,406
Placer	8,378	1,513	
Silver Cliff	854		
Grape Creek	801		
Total	53,425	47,097	22,889

Production of iron and steel by the Colorado Coal and Iron Company.

Products.	Quantity.
1882.	
Merchant bar, mine rail, etc ....short tons..	3,883
Pig iron ....do....	24,303
Castings ....do....	2,752
Muck bar (four months only) ....do....	1,253
Nails (four months only) ....do....	807
Spikes (six months only) ....do....	251
Steel ingots (eight months only) ....do....	20,919
Steel blooms (eight months only) ....do....	18,068
Rails (eight months only) ....do....	16,139
Total	88,375
1883.	
Merchant bar, mine rail, etc ....short tons..	4,568
Pig iron ....do....	24,718
Castings ....do....	1,332
Muck bar ....do....	3,301
Nails ....kegs..	62,968
Spikes ....do	7,581
Steel rails ....long tons..	16,518
1884.	
Merchant bar ....short tons..	2,002
Mine rail ....do	783
Pig iron (running ten months) ....do....	15,836
Castings ....do....	653
Muck bar ....long tons..	2,945
Nails ....kegs..	63,350
Spikes ....do....	1,570
Steel rails (four and a half months) ......long tons..	3,598

Wyoming.—Large beds of iron ore of excellent quality exist in the Seminoe mountains, in Carbon county. Some of this ore has been shipped to smelting works at Salt Lake City and other western points, but no record of the output is obtainable. The red color of the oxide here renders it suitable for paint, and considerable quantities are used for that purpose. In Laramie county, about 25 miles northeast of Laramie City, occurs an enormous mass of ore, which is called the Iron mountain. This locality is capable of furnishing indefinite quantities of iron ore.

Montana.—Iron in some form occurs in almost every county, but as yet none has been manufactured. Some very fine beds exist in the Yellowstone valley.

Dakota.—Iron ore is also found in Dakota, but not in sufficient quantity or purity to render its extraction profitable.

New Mexico.—In New Mexico the deposits of iron ore are numerous, extending from the Raton mountains to the Placer and Sandia mountains, overlooking the Rio Grande. It is found of excellent quality near Las Vegas; while south of Santa Fé, in the Placer mountains, there are three veins (from 3 to 8 feet in width) of good ore. At the Hanover copper mine there is a heavy supply of iron ore, partly magnetic, partly a red hematite, forming a continuous ridge some miles in length. On the Rio Puerco, associated with the coal, occur frequent bands of iron ore of similar quality to that mined formerly at Marshall's mine in Colorado, and in far greater quantity. East of the Gallinas range, and about 30 miles west of Socorro, in Socorro county, there is a large tract of land covered with nodules of iron ore varying from 100 to 500 pounds in weight, the ore being unusually pure and good. It has been shipped in large quantities for flux to the Cerillos smelter, the La Joya smelter at Socorro, and the Magdalena smelter at South Camp, in the Magdalena mountains. Good iron ore occurs also in the Santa Rita, Burro, and other ranges in the southern portion of the Territory.

IRON ON THE PACIFIC COAST.

By C. G. Yale.

California.—There are many deposits of iron ore on the Pacific coast, though very few have been opened and worked. While there is plenty of ore, fuel is scarce. The only mine in California being worked is that of the California Iron and Steel Company, at Clipper Gap, Placer county. The furnaces of this company, at Hotaling, in the same county, produced 4,500 tons of iron in 1881, and in 1882, after 990 tons had been made, a fire destroyed the works. These were rebuilt and again commenced work in 1883. In 1884 the output was 1,926 tons, the works having been closed part of the year on account of the low price of iron. Most of the output of 1884 was marketed in San Francisco, and sold readily (Nos. 2 and 3) at $32 per ton, being used in making car wheels. The company owns about 10,000 acres of land, a large part of it timbered. The furnace plant at Hotaling has a capacity of from 30 to 40 tons a day. The fuel used is charcoal, of which there is consumed about 100 bushels to the ton. With other expenses of manufacture, it costs to make the iron there about $18 per ton. The freight to San Francisco is $2.75 per ton, which, added to $18, the cost, makes $20.75. There are 177 men employed, and they distribute in the county of Placer about $12,000 a month. There has been no boiler-plate suitable for shop work made on the Pacific coast; but the California Iron and Steel Company has now, in addition to the plant at Hotaling, large malleable iron works and puddling mill at Emeryville, on the line of the Central Pacific railroad, in Alameda county, on the border of San Francisco bay. There are rolling mills in connection with the works. Mining work has been continued, though the furnace has been stopped, but the latter will be put in blast in the spring of 1885.

A deposit is being opened in El Dorado county, between the middle and south forks of the American river, about 8 miles from Folsom. The vein is about 3 feet wide and carries a high percentage of iron. Attempts have been made to work the magnetic iron sands of the ocean beaches along the California coast, where extensive deposits exist, but without practical success. Specimens of iron ore from twenty-one out of the fifty-two counties of California are on exhibition in the museum of the State mining bureau.

California imports each year large quantities of pig, merchant, and scrap iron. The importations of pig iron in 1883 were 24,980 tons, and in 1884 12,685 tons. Until the establishment of the Pacific Rolling Mills scrap iron had but little value. It would not pay to collect and ship East, consequently a great deal of old iron and steel was thrown into out-of-the-way places, where it was suffered to pass into slow decay by rust or be buried out of sight and knowledge by the gradual accumulation of other rubbish. But of late years this has been changed, and large quantities of domestic scrap are now being received at the iron works on the Potrero. Those works have also received much old iron from foreign ports, originally from Valparaiso, but recently from Europe, in about 500-ton lots, brought by the ships for dead weight. A large portion comes from London, and a good deal from Antwerp and Hamburg. In London it costs about 50 shillings, the duty is about 27 shillings, and average rate of freight about 20 shillings per ton. The Valparaiso shipments, formerly so heavy, are comparatively small now. The European scrap iron can be had for less money, and is of a better grade and more carefully selected. The scrap is all sorted before being shipped, and is ready for use on arrival. There are only three local buyers of scrap iron in quantities—the Pacific Rolling Mills, the Judson Manufacturing Company, and the Pacific Iron and Nail Works. They consume among them probably over 12,000 tons of scrap iron a year.

There are several large iron-manufacturing establishments in the vicinity of San Francisco, including foundries, rolling mills, nail works, etc., and these use most of the iron produced on the whole coast, besides large quantities imported from the Eastern States and from Europe.

The following table, compiled by Mr. J. W. Harrison, shows the importation, consumption, and price of pig iron at San Francisco, the price being that of the Glengarnock brand, the grade mainly used:

Consumption, imports, and price of pig iron at San Francisco.

Years.	Consumption.		Imports.		Price.
	White.	Soft.	White.	Soft.	
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Per ton.*
1880	976	10, 773	840	12, 362	$26 00 to $38 00
1881	1, 659	13, 518	300	8, 302	24 50 30 00
1882	989	19, 170	1, 502	18, 491	28 00 35 00
1883	1, 176	20, 674	1, 838	23, 142	24 50 27 50
1884	1, 596	10, 263	465	12, 220	22 00 26 00
Average for the past five years	1, 279	14, 879	989	14, 903	28 15

Oregon.—The Oswego charcoal furnace at Portland, Oregon, has recently been out of blast on account of the low price of iron. Its output in 1884 was mainly consumed in Oregon.

Washington.—The Port Townsend iron works, Washington Territory, made no iron in 1883, and the furnaces were not in blast until December 6, 1884. In that month they made 500 tons of pig; they have now a capacity of 30 tons of pig iron per day, and it is expected to keep the works running steadily. Part of the product is sold there and part in San Francisco. The establishment of extensive iron works at Tacoma, Washington Territory, is proposed by a syndicate of English capitalists. The amount of money subscribed for carrying out the enterprise is said to be from £500,000 to £600,000. An expert from England has visited the iron deposits in the Skagit country and reports the ore as very fine.

Utah.—Iron ore in large quantities is found in several places in Utah. A company called the Norway Iron Mining and Manufacturing Company has been organized in the Territory to work certain iron mines in Mill Creek district, Morgan county. Three of the mines have been partially developed, and some 2,000 tons of iron ore are now on the dumps. From analyses made of the ore by Mr. John McVicker, of Salt Lake City, it is found to contain from 56.12 to 65.08 per cent. metallic iron. The owners think they can make pig iron for $15 per ton. A sample of the brown ore from these mines was analyzed by Mr. F. M. Bishop, with the following result:

	Per cent.
Metallic iron	56
Silica	3
Carbonate of lime	4.5
Alumina	4.3
Sulphur	Trace.

The most important iron deposits occur in Iron county. The iron belt here is over 3 miles wide and commences several miles north of Iron Springs, running in a southwesterly direction to Iron City, a distance of over 16 miles. One of the most prominent points in this belt is Iron mountain, 1,500 feet above the surrounding plain. The central part of this belt, Desert mound, is 6 miles long and 3 miles wide. The country rock is granite, "porphyry," and limestone. This limestone is used as flux. The ore is hematite and magnetite, and it is claimed that it is a fine Bessemer ore. The quantity of ore in sight is very great. The following analyses are reported:

	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Iron	64.00	62.60	60.90
Phosphorus	.12	None.	None.
Sulphur	.13	.12	.08
Silica	5.20	4.80	5.80

In Iron Springs district are the Eclipse, Great Western, Lindsay, and Northern Cross iron mines, which are more or less developed. The

Lindsay No. 1 and Lindsay No. 2 have both yielded iron ore for lead flux. In Pinto district, Iron county, are several iron mines. There are large beds of coal from 4 to 18 feet in thickness, within 25 miles of the Iron county deposits of iron ore.

Iron ore is found in Tintic district, Juab county. It accompanies numerous deposits of silver-lead ores, being valuable on account of its percentage in gold and silver, and is used as flux. At present the lead smelters derive their greatest supply of flux from Tintic. In this district the iron ores occur in a belt 2 miles long and over 1,000 feet wide, bearing northeast and southwest. These ores are principally found in Tintic as bedded deposits in limestone; they are not suited for any other purpose than flux on account of their impurities. The principal deposits are on the mountain side at and near Dragon Hollow, which leads from Silver City across the summit of the Oquirrh range. The ore breasts here are from 40 to 50 feet high. From 150 to 200 tons of flux is daily extracted from the Tintic mines. From Billings's brown hematite iron mine, in this district, several thousand tons of ore have been used as flux in lead smelting; the market value at the smelter is $7.50 per ton. The Dragon iron mine, also in Tintic district, has yielded about 50,000 tons of ore for flux in lead smelting in the Jordan valley. The composition of Dragon ore is as follows:

	Per cent.
Metallic iron	61.60
Silica	3.20
Sulphur	.07
Phosphorus	.29
Manganese	1.30

Iron ores are mined in many other localities in the Territory, being used in fluxing siliceous silver-lead ores. At Smithfield, Cache county, beds of micaceous hematite 60 feet thick are said to occur.

On account of the high freight rates from the East, and the consequent high price of iron, and in view of the important coal deposits of the Territory, it is thought that under proper management the manufacture of iron in Utah could be successfully undertaken.

Arizona.—It is stated that iron ore occurs in many parts of Arizona, and some very fine beds of hematite are reported in Gila county. But as yet none of the beds are worked.

Idaho.—Iron ore is utilized to a limited extent as a flux in lead smelting.

Meteoric iron.—Several masses of meteoric iron have been found in the Pacific division, the largest in Arizona, and of less size in California. While these have no economic value, their occurrence is of interest. One meteorite was picked up in California many years ago near the town of Shingle Springs, El Dorado county, the weight of which was about 85 pounds avoirdupois. In 1880 another, weighing 1,870 ounces troy, was found in the Ivanpah mining district, San Bernardino county, the surface of this mass being deeply indented with concave depressions. An analysis of this meteorite, made by Mr. Gustav Gehring, showed it to contain:

	Per cent.
Iron	94.456
Nickel	4.869
Cobalt	.261
Silica	.041
Sulphur	.004
Phosphorus	.002
Carbon in combination	.115
Graphite	.067
	99.815

Hardness, 3.75; specific gravity, 8.076.

There is now in the State mining bureau of California a meteorite weighing 410 ounces troy, which was obtained a few years since from the natives on Portage bay, Chilcoot inlet, Alaska. General Carleton, in 1861, at Tucson, Arizona, had his attention called to a large meteorite which was there being used as a blacksmith's anvil. This mass, which weighed 632 pounds, was sent by General Carleton to San Francisco, and it is now in the hall of the Pioneer Society. It contains, according to an analysis made by Mr. C. G. Brash:

	Per cent.
Iron	81.56
Nickel	9.17
Cobalt	.44
Copper	.08
Phosphorus	.49
Silica	3.63
Protoxide of iron	.12
Lime	1.16
Magnesia	2.43
Chlorine, sulphur, and chromium	Traces.
	99.08

AMERICAN BLAST-FURNACE PROGRESS.

By John Birkinbine.

The progress made in all branches of iron metallurgy has been more marked in the last ten years than perhaps ever before, and a retrospect for a decade shows wonderful changes which have followed each other so rapidly that it is difficult to even summarize them. A history of what has been accomplished in iron and steel manufacture since 1874 would have to be printed almost as soon as it was written to be up to date, and would cover nearly every detail of installation or appliances.

When, however, we look back to the earlier days of iron manufacture in the United States we are still more impressed with the strides which have been taken. This progress has not been restricted to any one branch, but in some specialties the advance has been more pronounced than in others, and a comparison of the earlier practices and results in any one industry with the processes and output of the present time will be most instructive.

In this connection a brief résumé of the manufacture of pig iron will perhaps be as good an illustration as is required, not because it is more marked than some other branches of metallurgy, but on account of the wide distribution and variety of arrangements of blast furnaces, these establishments now existing in twenty-six States and two Territories.

The old charcoal furnaces.—Fifty years ago a typical blast furnace could have been described as a stone stack 30 feet square at the base, 20 feet square at the top, and 30 feet or less in height, pierced by one working or forepart arch in the front and one or two tuyere arches on the sides; but one tuyere, however, was ordinarily used. The forepart arch was fitted with a tympstone, and a forehearth extended out to a damstone. Blast was delivered cold through clay tuyeres, and between the blast nozzle and tuyere proper there was an annular space, through which fully as much air was at times drawn by injection as was delivered through the nozzle under the low pressure of one-half pound to 1 pound per square inch.

A high breast or overshot water wheel operating wooden blowing tubs furnished the blast, which was carried through wooden or tin pipes to the tuyeres, and the wheezing of these tubs could be heard at considerable distances from the blast furnace.

The casting house, top house, blast house, stock houses, and store were often frame buildings, but the extensive stables, the smith shop, the "mansion," and the office were generally of more substantial construction.

The tuyere and forepart arches were covered with heavy iron "sows," cast at some neighboring plant; and similar castings in segments of a circle formed the "ring plate" placed in the offset of the masonry on which the "inwalls," built of shale or slate, were raised. The bottom, the crucible (or hearth), and the boshes, were built of sandstone, nicely jointed, the masonry being carried out against the buttresses or corners of the stack, which were in many instances braced by heavy timbers and iron rods, to preserve the masonry from injury by expansion.

The thickness of the hearth walls was seldom less than 3 feet, and the crucible inclosed by these walls was ordinarily from 5 to 7 feet in height and square in section, the bottom being from 24 to 27 inches square. From this point the boshes were battered out so as to slope about 40° from the vertical, or 10 inches horizontal to 12 inches vertical, and the section worked from a square into a circle, until the greatest diameter at top of bosh (generally 8 to 9 feet) was reached; from there the inwalls were drawn in until the top or throat of the furnace measured from 2½ to 3 feet in diameter, and over this an iron plate with a hole 20 to 24 inches in diameter was placed.

The location selected for the blast furnace was generally on the bank of a stream which furnished the water power, and close to ground sufficiently elevated to permit of constructing a bridge house from the top of the furnace stack to the general level, on which were placed the coal houses, ore supply, etc.

When ready to start, the furnace was filled with charcoal, lighted on top, and when the fire reached the tuyeres blast was applied, more charcoal was charged, and the burden of ore and limestone, finely broken, was slowly increased; this generally resulted in a production of from 20 to 30 tons of cold-blast iron per week after the furnace was fairly in operation. The fuel used was exclusively charcoal, which was charged into the tunnel head by baskets; the ore and flux were fed by boxes; the number of boxes of ore and the number of baskets of charcoal formed the relation of the "charge." The weekly output above mentioned was about the average; at the commencement of a "blast" the product was small, but as the campaign progressed it became augmented owing to the enlargement of the crucible and steepening of the bosh due to the stones being cut back by the intense heat at the zone of fusion. The walls were too thick to admit of conducting the heat away with sufficient rapidity to maintain the original slope given the furnace.

The small opening in the tunnel-head plate insured thorough distribution of the stock in the limited area of the throat of the furnace, thus aiding to secure regularity of operation. From this opening flame was constantly emitted, varying with each stroke of the blowing machinery. At many iron works pots, kettles, and stove castings were made directly from the furnace by ladling the molten iron out of the large forehearth. The product of the furnace was carried in wagons often to distant localities, the castings being disposed of in cities and towns, or the pig iron worked into blooms or anchovies at forges. Often a forge was operated in connection with the furnace.

Each furnace maintained a general store, and most of the pay due the woodchoppers, charcoal burners, ore miners, teamsters, furnacemen, etc., was expected to be expended at the store. In fact it has been claimed that some old managers would reduce the balance due a workman at the end of the year if it was believed that he had "saved too much," or rather "traded too little." The question of "company stores" has caused considerable discussion at various times, and in some States legislation now nominally forbids them, or places restrictions upon their management.

As most of the blast furnaces were located in a section of the country where winter interfered with out-of-door work, and as their construction was such that the interior was rapidly destroyed, the practice of making one "blast" every year was followed. Wood would be cut during the winter, and as soon as the weather permitted of doing so, hearths would be leveled among the cut timber, wood would be hauled to these hearths, and there piled into meilers covered with leaves and earth and fired. After about two weeks of carbonization the charcoal would be drawn, and hauled by wagons to the furnace. When a sufficient quantity of charcoal had accumulated to insure a regular supply, the furnace was blown in, and except for some accident, low stage of water, or other disturbing cause, it would be continued in blast until all the charcoal which had been made in the coaling season was consumed. This generally permitted the furnace to be active eight or nine months in each year.

The "blowing in" was an important event at the furnace, generally requiring several days, and was ordinarily an annual occurrence each spring; the date being fixed by the possibilities of securing a supply of fresh charcoal. When the furnace was "blown out" it would be cleaned out, the old hearth (which had become considerably enlarged) would be removed and a new one put in place, when the same yearly routine would be continued.

The ores used were chiefly brown hematites, which are easily smelted in the furnace, and they were mixed with a small percentage of lime and clay to flux impurities and make cinder. The cinder was allowed to flow continually over the damstone, and form into cakes upon stones laid in the floor of the casting house. When pig iron was cast the iron passed through one long runner to feed pig-iron molds at right angles to it, one side of the casting house being devoted to pig iron and the other side to cinder.

While many features of plant or practice as described have been abandoned there are still instances where all of the above-mentioned appliances or methods are in use, and individual plants can be cited for which this description would be practically a record of present arrangement and management. Such instances are, however, becoming less frequent each year.

The stone masonry of the older stacks was often quite massive, and in many cases they were constructed with such integrity that they have sustained successive enlargements of bosh and increase in height. Some stone blast-furnace stacks are still active, which are more than a century old. (The Cornwall charcoal furnace in Lebanon county, Pennsylvania, has been an active iron-producing establishment since 1742, and ranks as the oldest plant in operation in the United States.) The openings provided for a working or forepart arch and for tuyere arches were liberal in width, but generally restricted in height, and did not permit of elevating the tuyeres to points now considered advantageous.

The tin blast pipes and light fixtures stood all the work demanded of them, for even where the water power was adequate and the machinery strong enough an old-time founder would not blow hard for fear of destroying the fuel, or, as he expressed it, of "blowing the charcoal to pieces."

While the construction of the blowing apparatus appeared cumbrous and crude, it gave evidence of careful thought and good workmanship. The wooden blowing tubs were cylindrical or rectangular in form, from 5 to 7 feet in diameter, or square, and from 2 to 5 feet stroke. They were formed of segments or strips cut from 1-inch boards, generally pine, glued and doweled together and then turned or planed to smooth surfaces. There are examples of both cylindrical and rectangular wooden tubs still in use. These tubs, when lined with apple or other hard wood, were very durable. Hard-wood segments were also placed within tubs made from pine staves secured with bands. Large wooden pistons with leather edging were fitted in the tubs and connected with square wooden piston rods working in square stuffing boxes. The blowing tubs, when single acting, had the outlet valves in the piston, and, when double acting, these valves were in the ends of the tubs. Some of these engines were known as "pacers," owing to the motion of the two counter-weighted beams, which were connected with the two blowing pistons, but the ordinary appellation for all blowing apparatus was "the blast," whatever its design. A popular arrangement of "the blast" consisted of two vertical, single-acting, wooden blowing tubs placed over opposite ends of a vibrating beam which received motion from a crank on the water-wheel shaft. The air was admitted through valves in the piston during the down stroke and discharged into a third tub placed over the two just described; this third tub had valves in the bottom communicating with the two operating cylinders, and a large floating piston forming the top was weighted with iron to secure the pressure desired; it rose and fell with each stroke of the operating cylinders.

These mechanisms had the advantages of being positive in action, durable, and efficient for moderate pressures of blast, and as long as the water power was ample they served the purpose for which they were designed. But the demands of the plant rapidly reduced the forest area and decreased the average flow of streams, in many cases restricting the output of the iron works by a deficiency of power.

The location of the older furnaces, however, generally indicated a knowledge and foresight which have failed to characterize some later constructions, and the questions of ore or fuel supply, water power, and transportation received careful consideration. The enterprise and pluck which instigated the location of iron works in the midst of dense forests, far from other settlements, and where all material and supplies had to be transported long distances over roads made for the purpose, were in that day as notable as some more prominent ventures of the present time. The engineering ability displayed in the choice of location, the improvement of water power, the construction of the plant, and the laying out of roads, commands our respect when we remember the meager facilities as compared with the machines, tools, and instruments, or the literature accessible at the present time.

The selection of the best ore deposits was not a mere stroke of fortune, but when the state of chemical knowledge and the paucity of mining appliances of fifty years ago are recalled, we may well be surprised to note the wisdom which guided the old ironmaster to pick out from an unbroken forest the ores whose quality was the best, and which, in some cases, have been worked to the present, with ample indications for a future supply.

Use of mineral fuel.—As the country was developed the demand for iron necessitated more furnaces or larger outputs from existing plants, and as the capacity of a charcoal plant was dependent upon the timber available, the reduction of fuel per ton of iron claimed attention. This was attained in part by more careful selection and preparing of ores, by heating the blast, and by improved methods of carbonizing wood. About the time that the hot blast was coming into favor the employment of mineral fuel was being investigated, and soon anthracite coal and bituminous coal were competing with charcoal as a blast furnace fuel. The first experiments with mineral fuel were conducted in furnaces arranged to use charcoal, and the results demonstrated that to obtain satisfactory operation changes in the plant were necessary. Anthracite fuel, or coke, can be, and have been, used in furnaces arranged for charcoal, and several instances of this are on record. In 1879 the problem was satisfactorily tested at Pine Grove furnace, Cumberland county, Pennsylvania, where, without going out of blast, the furnace was run first on charcoal, then on coke, then on mixed coke and anthracite coal in varying proportions, then on all anthracite coal, then on coke, and back again on charcoal. As a matter of interest a résumé of this experiment is presented.

The Pine Grove furnace has been in nearly constant operation since 1770, and is an old stone stack, raised to meet the more modern practice, and equipped with steam blowing machinery of ample power. At the time of the experiment (February to August, 1879) the dimensions of the furnace were:

	Ft.	*In.*
Diameter at bosh	9	4
Working height	36	6
Diameter of crucible	4	2

The furnace was closed by bell and hopper, and was blown with 3 tuyeres. During the experiment the blast was heated to an average temperature of 600° Fahr.

Summary of results of smelting brown hematite iron ore with charcoal, coke, mixed fuel, and anthracite coal at the Pine Grove furnace, Cumberland county, Pennsylvania. (*a*)

Items from record of working.	Fuel used.					
	Charcoal, February, 1879.	All coke, March 22 to April 2, 1879.	Anthracite, 81.5 per cent.; coke, 18.5 per cent., April, 1879.	All anthracite, April and May, 1879.	Anthracite, 55 per cent; coke, 45 per cent., May, 1879.	Charcoal, August, 1879.
Pounds of fuel consumed per ton of pig iron	2,531	3,494	3,473	3,871	3,271	2,650
Pounds of ore and flux carried per pound of fuel	2.8	2.32	2.47	2.14	2.34	2.64
Tons of iron made per week, average	95	70	78	58	77	101.6
Percentage of iron yielded in furnace	38.26	40	38.40	38	43.3	40
Percentage of lime to ore burden	22	44	50	47.4	50	24.4
Average cubic feet of blast per minute	1,896	2,435	2,749	2,434	2,473	2,301
Average cubic feet of air per ton of iron	197,084	323,845	338,187	398,679	317,170	216,243
Average cubic feet of air per pound of fuel	77.8	92.66	96.13	103	97	81
Average pressure of blast in pounds	.77	1	4.25	4.75	2.5	1.25
Tuyere area in square inches	47.7	28.9	14.7	14.7	14.7	42.5
Least time that stock was in furnace, hours	12.5	20.5	22	31	25	9.5
Grade of iron	2.4	3	2.7	3	3	2
Duration of experiments, days	28	10	10	23	19	31

The tons are 2,260 pounds each for pig iron, 2,240 pounds for everything else.

Since the above record the furnace has done much better work than here given, but the table is presented to indicate approximately the action of different fuel under similar conditions, and not as a remarkable furnace performance.

The statement shows that the furnace averaged a larger output on lower fuel consumption per ton of iron, and with less air per pound of fuel when fed with charcoal than when using other fuels, and that a mixture of coke improved the operation of the plant when anthracite coal was used. It should be noted that these experiments were limited by the fuel available during labor disturbances.

Improvement in blast furnaces.—The successful employment of mineral fuel in blast furnaces is mentioned by various authorities at different dates, but it may be considered as having been satisfactorily accomplished commercially in 1840. The result of the change of fuel necessitated many alterations in blast-furnace plants to secure the best results, not only in an increase of power for blowing machinery, but in size of furnace, the diameter of the boshes, the dimensions of tuyeres used, and many details of construction which were modified from year to year. The accessibility of large quantities of coal permitted of increasing the size of furnaces beyond what was deemed advisable for those using charcoal.

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a "Experiments with charcoal, coke, and anthracite at Pine Grove furnace, Pennsylvania," by John Birkinbine; Transactions American Institute of Mining Engineers, Vol. VIII., pages 168 to 177.

Enlargement of blast furnaces.—The sizes of the furnaces were increased both in diameter of bosh and in height, and the augmented height, together with the necessity of placing the plant convenient to transportation facilities, caused the abandonment of "bank furnaces," and the erection of artificial means for raising the stock to the tunnel head. The use of hot blast of course became essential, and the growth of this important feature of a blast-furnace plant was quite marked, and many changes were made. The enlargement was not rapid up to the year 1873, when blast furnaces 17 feet in diameter at the bosh and 60 feet high were considered large, and a product of over 60 tons of pig iron a day was phenomenal at that date. At present American blast furnaces have been constructed 21 feet in diameter at bosh and 86 feet high, and have produced over 300 tons of pig iron per day. This size is not as great as that of some foreign furnaces, but appears at present to be considered the economic limit. The increased output is not due alone to the dimensions of the furnace, but is owing to a combination of causes, among which may be mentioned steep boshes, large crucibles, increased volume, pressure, and temperature of blast, the careful selection and thorough preparation of the stock, and the study of the chemical reactions in the blast furnace. The technical problems of blast-furnace management have become generally appreciated only within the past decade. Ten years ago the employment of a furnace chemist was unusual, but at present laboratories are considered an indispensable feature of modern plants.

Blowing apparatus.—The experiments made at charcoal furnaces demonstrated that mineral fuel required more powerful blowing machinery than that given by water wheels and wooden blast tubs, and except where there were unusual water facilities steam power was soon employed. The mechanism substituted generally consisted of one or more horizontal cylinders connected by gearing with a horizontal steam engine; in some cases a steam engine was substituted for the water wheel and the old wooden blowing tubs were operated by it. Generally, however, iron blowing tubs were placed in connection with steam engines.

The horizontal cylinders soon gave way to others placed vertically and connected directly with the steam cylinders. These have been arranged in various ways. A steam cylinder has been placed between two vertical air cylinders, or a single air cylinder has been placed below the steam cylinder; but the prominent type of blowing engine now in use is an air cylinder supported on housings or columns above the steam cylinder, with a cross head between the two, and fly wheels outside of steam cylinder, connected by rods with the extremities of the cross head. In isolated cases beam condensing engines have been used and large expenditures have been made for them. With but few exceptions, the blowing engines now in use are non-condensing. In late years the direction of improvements has been towards increasing the speed and thus getting large capacity from small engines. This has mainly been accomplished by the arrangement of air-cylinder valves. A combination of one or two horizontal steam cylinders operating by crank shafts two vertical air cylinders is also in use.

Much time and investigation have been devoted to the manufacture of blowing engines, and they are among the more prominent types of American machinery. Some of the engines constructed for blast furnaces are very massive, and blowing cylinders 9 feet in diameter and 9 feet stroke are connected with some plants; but the prevailing sizes are 4 to 7 feet in diameter and 3 to 7 feet stroke. The increased speed of operation is at present having the tendency to reduce the length of stroke, and 4 feet represents that now generally preferred for the larger furnaces.

Tuyeres.—The intensity of blast necessitated the abandonment of open tuyeres, and iron forms were used. These were also so rapidly destroyed that water cooling became necessary, and this was accomplished by making the tuyeres of an inner and an outer shell, the water circulating in the annular space; or coils of pipe were used, either bare or incased with iron which was cast about them. Later modifications of these have sprays injected into the annular space, or the shells are formed of bronze, or the coils are wound about grooved castings, or about wrought-iron forms. They are also set in "water-breast" castings, which fit aronnd the tuyeres and through which water circulates.

Refractory linings.—The intensified combustion caused by the higher temperature and augmented pressure of the blast rapidly destroyed the refractory linings, and the hearth and boshes of sandstone gave way to those made of less thickness with firebrick. The shafts or in walls of the furnaces were also lined with the same material. Owing to the thickness of the walls near the tuyeres the intense heat was not conducted away with sufficient rapidity, and it became necessary to cool the mass of firebrick artificially. For this purpose jackets or blocks of cast iron, in which coils of pipe were cast, wrought-iron jackets, sprays of water, and a series of wrought-iron buckets surrounding the crucible, have been used, and the thickness of the walls is greatly reduced. The merits of various shapes of firebricks or the composition of the clays from which to form them, or make joints in laying them, have been liberally discussed; and some furnace managers hold as tenaciously to certain clays or special bricks as the older ironmasters did to pudding stones from particular quarries which were esteemed especially valuable for blast-furnace bottoms. The question of refractory material is by no means unimportant, and it has been demonstrated that often different bricks are necessary to withstand the intense heat of the crucible, the attrition of stock on the inwalls and boshes, or the dissolving action of gases near the tunnel head. It is essential to have good material to lay good brick with, for otherwise the integrity of the masonry is jeopardized. The tendency towards the use of larger blocks and a variety of special forms seems to have reached its maximum, and ordinary sizes and shapes of firebricks are now generally preferred.

Blast-furnace stacks and fixtures.—The character of the blast-furnace structure itself has also changed, and the old stone stacks, when used, were either topped out with a circular shaft of brick masonry bound with iron, or by casings of wrought iron inclosing the inwalls. Brick piers supporting a brick shaft banded with iron are also used, but the prevailing type of a modern blast furnace is a shell of wrought iron carried on a circular mantle supported by a series of columns or brackets.

The construction of the blast furnaces away from banks necessitated either expensive arches sustaining the hot-blast stove and boilers at the level of the tunnel head, or the erection of chimneys sufficiently high to make a draft superior to that of the furnace itself, thereby drawing away in suitable flues the gases from the top of the furnace and bringing them to the ground level. This caused the improvement of closing the top of the furnace by means of plates or doors; following which charging bells were introduced. These consist of a conical bell of cast or wrought iron closing against a hopper of the same material. Among the modifications in form were a double bell or an annular ring fitting against a fixed bell and the hopper. Methods of sealing the top, to prevent the gases escaping when the bell is lowered, have also been applied. The modifications of the charging bell have been mainly in the direction of securing a more uniform distribution of the stock at the throat of the furnace, and the proportion which the size of the bell bears to the throat of the furnace, when taken in connection with the character of the stock used, has a most important bearing upon the successful working of a plant.

The forehearth mentioned in connection with the older charcoal furnaces was gradually reduced in size; cast-iron dams, generally water cooled, were employed to protect the tapping hole; and the arrangement ordinarily introduced for tapping cinder at suitable intervals was an opening made in the brick masonry immediately over the dam, the sides of which were protected by iron cheeks supporting the cast-iron water-cooled tymp, which took the place of the tympstone. Some furnaces have been operated with apparent success with dry dams and tymp, or with neither dam nor tymp, using simply openings in the brickwork. Other arrangements than a tymp have been used, among which may be mentioned water-cooled cinder blocks through which the slag could be tapped, and slushing cinder blocks, whose function is to vent large volumes of slag through an opening of suitable area closed by a door. The forehearth, though considerably curtailed in length, is still used to a limited extent; but it seems to serve no purpose other than providing room for iron when the crucible is too small, or for permitting the furnace to be "worked" and allow the excess of fuel (which should never have entered the tunnel head) to be removed. The "working" is performed by the aid of bars and shovels several times daily.

Blast-heating appliances.—The original hot-blast stoves were a series of horizontal cast-iron pipes heated from grates, but the introduction of furnace gases as fuel caused the substitution of combustion chambers either in front of or below the pipe chambers. Many varieties of shapes, sizes, and arrangements of hot-blast pipe have been tried, and quite a number are employed in different sections of the country, each having its champions. The prominent forms of iron pipes used in hot-blast stoves are known as U pipes; that is, two vertical pipes connected at the top. The pistol pipes, which are castings resembling somewhat the shape of a pistol, have diaphragms running through the centers, so that the blast passes up one side of the diaphragm and down the other. Straight pipes with diaphragms have also been used, and the U pipe suspended from above has been introduced to a limited extent.

The merit of the excessive temperature, or what may be termed superheated blast, is in dispute among competent authorities, but the tendency in late years has been to heat the blast to a temperature above what is believed to be reliable with iron pipes. This has been secured by constructing hot-blast stoves of masses of firebrick, the gases and blast alternately passing through them in opposite directions either by means of parallel flues or of openings in checker work. These stoves require that the valves controlling them should be protected by water cooling, and it is claimed that as high as 1,500° Fahr. has been secured regularly by their use, a safe limit of iron pipe stoves being considered to be 1,050° Fahr. To supply blast at a temperature of 1,500° or more demands that all tuyere fixtures and blast connections should be protected either by refractory linings or by water cooling. The introduction of regenerative stoves and the friction of the gases in passing through long flues and checker work of brick masonry necessitated the construction of tall chimneys to create the required draft, and such chimneys are now connected with blast-furnace plants using these stoves.

Boilers.—The type of boilers connected with American blast furnaces has generally been long cylindrical or double-return flue boilers, in some cases the length being 80 feet. Tubular boilers have also been used, the objection to them being the difficulty of cleaning, and lately water-tube boilers with cleaning appliances have been adopted at several blast furnaces.

Gas connections.—As all gases coming from blast furnaces carry with them a large amount of furnace dust, consisting of fine ore, ground fuel, ashes, etc., there is likelihood of deposit wherever the current is retarded. To overcome this trouble various means have been used, the most successful being the employment of large chambers provided with cleaning doors, and the use of jets or sprays of water to condense the gases and deposit the dust. Small flues through which the gas is forced to maintain considerable velocity, alternating with larger receptacles where the velocity is retarded, seem to give the best satisfaction. To relieve the plant from overhead flues late practice has brought the gases down from the tunnel head by a large "downcomer" or "downtake," terminating under ground, where it connects with a series of masonry flues extending to the boilers and hot-blast stoves. These flues are either covered loosely with plates of iron and luted with clay or are provided at intervals with explosion doors. Masonry flues, however, must be large enough for workmen to enter for cleaning out the dust, and they seldom are tight, so that air obtains access, either causing explosions or igniting the gases, thus detracting from their efficiency under the boilers and in the hot-blast stoves. A blast furnace when working properly ordinarily makes sufficient gas for generating steam and heating the blast, and often has an excess escaping from a "bleeder" or relief valve placed on the "downcomer." The gases are admitted together with air for supporting combustion, through burners, to the boilers and hot-blast stoves.

Stock elevators.—Inclined planes for hoisting the stock for the furnace, although possessing the merit of removing the stock sheds away from risks of fire, are not often employed. At the present, in their stead, vertical hoists are used, the motive power being steam, air, or water. The steam hoists in general use may be divided into those which, by means of gearing, transmit power from steam engines to winding drums, and those in which the piston, moving within a long vertical cylinder, turns by means of a rack and pinion a large wheel or drum over which the ropes sustaining the cages pass. Pneumatic hoists are operated by means of compressed air acting upon a piston in a long cylinder generally the height of the furnace. The water-balanced hoist is practically the only method employed which may be classed as hydraulic. This consists of boxes beneath the platform of the hoisting cages, which are filled with water at the top of the furnace until the weight is sufficient to raise the loaded barrows on the opposite cage. Some of the mechanisms of the furnace hoists make them almost automatic, and there is quite a variety of special features from which to select. Safety catches which engage in racks, or which force chisel blades into the wooden framing of the hoist in case of accident to the hoisting rope, are attached to many cages, and supplementary ropes are used as additional safeguards. The structures or towers in which the hoisting carriages (of which there are generally two) are placed are either constructed of brick, wood, or iron; as these towers must extend sufficiently above the top of the furnace to allow room for the cages and operating drums, they are often quite imposing structures. Wooden hoist structures are a constant menace to the furnace on account of fire; iron towers are most symmetrical, but are exposed to the weather, and the brick buildings are generally dark. Iron towers seem to be the most popular at present, and in some of them the pillars are made to serve as water pipes; but brick towers are the most reliable.

Handling and preparing stock.—The necessity for protecting stock from the weather would appear to be an undetermined question, for in some of the larger plants where the inclement weather of winter would be apt to give trouble no stock houses are used. The ordinary practice, however, and that most approved, is to use stock houses in which the ore, coal, and flux are brought by railroad cars and dumped into bins. There are some instances where the charge is made up complete into a large car, raised by inclined planes to the tunnel head, and there dumped; but the ordinary way is to fill the stock into charging barrows, raising these by hoist to the top of the furnace, where "top fillers" are supposed to empty them uniformly around the bell. An improvement is to lift the material in the ordinary charging barrows or buggies, and dump it directly on the bell from the hoist, thus doing away with the necessity of "top fillers."

It is only lately that the practice of charging together large and small pieces of fuel or ore into the furnace has been abandoned, but the recognized merit of the preparation of ore has made rock crushers popular, and they are now common at blast furnaces. Where the ores are carbonates, or contain much sulphur, they are ordinarily roasted, either in alternate layers of ore and fuel, forming piles in the open air, or in special structures of iron or masonry; but thorough desulphurization has not been accomplished with solid fuel, and gaseous fuel is employed to secure the best results. The extent to which roasting or desulphurizing ores is carried is not, however, commensurate with its importance, and this feature of practice is destined to grow in favor as its value is appreciated.

In studying the various details of blast-furnace construction and management the prevalence of particular designs or peculiar methods in certain districts is noticeable. In fact this system of copying from neighboring plants is so marked that in different sections of the country the prevailing features of plant and management have been quite distinct. The more intimate association of those interested in iron manufacture in technical and business organizations has broadened the views of the active men in this industry and broken up the uniformity which characterized individual localities; and the employment of blast-furnace engineers whose experience embraces more extent of territory than an individual manager can cover has done much to secure the adoption of the best features from all districts. There are, however, points of particular value to one locality which are and will be continued, but the peculiarities heretofore prominent for certain iron-producing districts are rapidly passing away.

Operation.—The present practice of operating blast furnaces varies as much from that of the past as the older and later methods of construction differ. Instead of filling a furnace with fuel and "blowing in" by nursing a mass of fire for several days (which had the effect of making the top of the stack the hottest, and left the crucible, which needs the most heat, the coolest part of the furnace), the plant is put into operation promptly. This can best be illustrated by quoting from a late paper (in Volume V. of the *Journal of the United States Association of Charcoal Iron Workers*) describing the start made at the Mont Alto furnace, Pennsylvania, a remodeled plant, which formerly followed the older practices as described:

"The fire was lighted at 3.40 o'clock a. m., Tuesday, August 14, 1883. Blast was put on at 6.40, a. m., August 14. First cinder was tapped at 9.40 a. m., August 14. First cast, of 5½ tons No. 2 pig iron, at 8 o'clock p. m., August 14. Second cast, of 8½ tons No. 1 pig iron, at 3.20 o'clock a. m., August 15, making a product of 14 tons of pig iron within twenty-four hours after lighting the fire, and within twenty-one hours after blast was put on. During the second twenty-four hours after lighting the fire the product was 30 tons No. 1 pig iron, and this quantity was about the average daily product."

The Mont Alto furnace is operated with charcoal, and the case is cited as a comparison with the former practice at furnaces using this fuel. While the record is exceptional, it indicates the course now most in favor, not only at charcoal furnaces but also at anthracite and bituminous-coal furnaces.

Instead of making one "blast" of eight or nine months each year, the desire of owners and managers is to maintain the plant in continuous action as long as possible; and records of three to seven years' campaigns can be presented. However, the American practice does not equal in average or maximum duration of campaigns the record of English furnaces; but it is probable that in our newer constructions as much iron can be made on a lining in comparatively short "blasts" as our British friends obtain by more moderate driving for a term of years. The thin walls and water-cooled appliances, if properly arranged, will maintain the shape of the furnace and insure longer "blasts" than heretofore.

The employment of chemical analysis for fuel, flux, ore, cinder, and gases, and a study of the operation of the furnace practically and theoretically, permit of forcing the plant to an extent formerly impracticable or impossible, and guide the manager in his direction. Instead of constantly changing the burden to correct irregularities which appeared only after the metal was made, the disturbing causes are recognized by gas or cinder analyses before the furnace is tapped; and determinations of the chemical composition of ores and fluxes permit of mixtures which produce iron of the desired character. The proportions of various parts of the furnace, the volume, pressure, and temperature of the blast, all combine under careful watchfulness to secure an output far in excess of what was believed possible.

Fuels.—In referring to the employment of mineral fuels mention was made of the relative merits of various combustibles for blast furnaces, which may be defined generally as being dependent upon their structure and chemical composition. They rank in the following order: Charcoal, coke, anthracite coal. Charcoal, being a pure fuel and very open in structure, rapidly oxidizes at a red heat at the tuyeres, and although the bulk is double that of coke a greater product is obtained from a charcoal furnace of the same size than from one using coke. Similar results follow the employment of coke as compared with anthracite, and many anthracite furnaces have been enabled to largely augment their output, without increasing the power of their machinery, by mixing coke with anthracite coal. It is, however, claimed on good authority that if a blast furnace is able to withstand the severe action due to a high pressure of blast, and the blowing engines are capable of maintaining such pressure, results can be obtained with anthracite fuel which will approach, if not equal, those secured by the employment of coke.

The pressure of blast commonly used at blast furnaces may be considered as ranging from 1 to 4 pounds for charcoal, 3 to 8 pounds for coke, and 6 to 14 pounds for anthracite, per square inch.

The direction for improvement in the use of anthracite coal apparently lies in blast-furnace structures carefully designed with special reference to the use of strong blast, and equipped with machinery, boilers, and hot-blast stoves, of ample power and capacity.

The proportion of furnaces using the various fuels, as given by the Directory to the Iron and Steel Works of the United States, by the secretary of the American Iron and Steel Association, on September 1, 1884, is as follows:

Furnaces.	No.
Total number of charcoal furnaces	232
Total number of coke furnaces	221
Total number of anthracite furnaces	221
Grand total	674

In the above classification all furnaces using bituminous coal as fuel are included in the category of coke furnaces, although some of them, as in southern and eastern Ohio and in northwestern Pennsylvania, use bituminous coal raw, either entirely or mixed with coke in varying quantities. Similarly the anthracite furnaces include all which base their charge on this fuel, although they may operate with anthracite and coke mixed.

In the manufacture of charcoal improvements have been in the direction of obtaining a greater yield from a given amount of wood. Ordinary meilers cannot be depended upon to average over 35 bushels (of 2,748 cubic inches) per cord of 128 cubic feet. As the earth cover of a meiler is far from being impervious to air or water, kilns constructed of brick masonry are used to a large extent, their general forms being rectangular, beehive, or conical, and of capacities varying from 30 to 100 cords. They average 45 to 50 bushels of charcoal per cord of wood.

For a number of years charcoal has been made in closed iron vessels or retorts, set over fireplaces; lately these have been growing in favor, and improvements in design or arrangement have increased their yield, so that 60 to 66 bushels of charcoal have been obtained from a cord of wood. A chemical plant is generally connected with retorts, and the vapors of carbonization are collected, condensed, and made into methylic alcohol and commercial acetates. Similar utilization of smoke has been made by exhausting the vapors from kilns and carrying them to appropriate condensers, stills, etc.

Raw bituminous coal has been and is used in some districts, but it is much inferior as a furnace fuel to coke, and there is also a great difference in the merit of coke from different localities for this especial purpose. It is not every coking coal which makes a good blast-furnace fuel. Coke is produced either in open heaps or ricks, in Belgian ovens, rectangular in section, or in beehive ovens. The latter seem generally to be preferred. In Europe the gaseous products from coke ovens are in some cases collected, and ammonia, tar, etc., obtained from them; but this has not yet been attempted in the United States, although it is probable that it will be done in the near future.

The best results obtained with anthracite fuel have been where comparatively small sizes of coal are used. The practice of charging very large lumps having been generally abandoned, coal of the size commercially known as "steamboat" has been substituted. It is probable that a still greater reduction in size would be advantageous were it not that the smaller coal commands a higher price.

Good furnace practice demands close attention to the character and condition of the stock charged into the furnace as well as to the manner of charging it; hence the use of crushers to reduce ore and limestone to more uniform sizes has become very popular.

Roasting of ores is pursued where they contain considerable amounts of sulphur, carbonic acid, or water, and the calcination of limestone previous to charging has also been tried. The roasting of iron ores is done in open heaps of greater or less size, in square or circular masonry structures, or in sheet-iron circular kilns provided with a bosh supported on columns or brackets, the fuel used being waste culm or slack or braize. To secure more thorough desulphurization gaseous fuel is necessarily used, the ore being charged into masonry chambers of comparatively small area, heated with gas, and the ore exposed to the oxygen of air while very hot.

Number and capacity of blast furnaces.—Although the number of plants using bituminous or anthracite fuel are the same (221 of each), and the number of charcoal furnaces only exceeds that of the plants using either of the mineral fuels by 11, the iron industry should not be considered as divided practically into three approximately equal parts, for the bituminous furnaces average larger dimensions than those using anthracite, and the anthracite plants are of greater size than those which depend on charcoal. Comparing the number of blast furnaces in the directories of July, 1882, and September, 1884, with the nominal maximum capacity, the following statement is presented to show how rapidly advances are being made:

Comparison between the number and nominal capacity of blast furnaces in July, 1882, and the number and nominal capacity of blast furnaces in September, 1884.

Furnaces.	July, 1882.	September, 1884.
Number of charcoal furnaces	250	232
Number of anthracite furnaces	224	221
Number of bituminous-coal furnaces	211	221
Total number of blast furnaces	685	674
Nominal capacity of charcoal furnaces ... short tons..	1, 125, 000	1, 275, 000
Nominal capacity of anthracite furnaces ... do....	2, 750, 000	3, 175, 000
Nominal capacity of bituminous-coal furnaces ... do....	4, 125, 000	4, 850, 000
Total nominal capacity of blast furnaces ... do....	8, 000, 000	9, 300, 000
Average nominal capacity per charcoal furnace ... short tons..	4, 500	5, 496
Average nominal capacity per anthracite furnace ... do....	12, 277	14, 366
Average nominal capacity per bituminous-coal furnace ... do....	19, 550	21, 945
Average nominal capacity per blast furnace in the United States ... do....	11, 679	13, 798

While this table shows the relative importance of each branch of the pig-iron industry, and indicates the improvement in blast-furnace practice in the two years, it is not claimed that the figures of nominal capacities represent the actual product; for the output of the blast furnaces in the United States in 1883 was as given below, and the proportion which this production bears to the nominal capacity is shown by percentages.

Proportion of actual production of pig iron in 1883 to the nominal capacity of the blast furnaces.

Furnaces.	Pig iron produced.	Percentage of nominal capacity.
	Short tons.	
Charcoal furnaces	571, 726	44. 8
Anthracite furnaces	1, 885, 596	59. 4
Bituminous-coal furnaces	2, 689, 650	55. 4
Total	5, 146, 650	55. 4

The year 1883 was one of business depression, and the percentages are less than would be found at times of greater prosperity; but as the nominal capacity is based upon all the blast furnaces being run to their utmost (which can never be the case), correction must be made by a liberal reduction from the totals of nominal capacity for idle or crippled works. On the other hand, the number of blast furnaces reported in the directories is always in excess of those ready to operate, and it is probable that the most equitable method of determining the present average capacities of the blast furnaces would be to divide the output of 1883 by the number of furnaces of each kind in blast. This method is also subject to error, because in time of depression the smaller plants are generally idle, and because the number of furnaces in blast is only correct on the specific date of the reports and not for the entire year. The figures for 1883 are as follows:

Average output of furnaces in blast in 1883.

Furnaces.	Number of furnaces in blast December 31, 1883.	Pig iron made in 1883.	Average output per furnace in 1883.
		Short tons.	*Short tons.*
Charcoal furnaces	84	571, 726	6, 806
Anthracite furnaces	118	1, 885, 596	15, 980
Bituminous-coal furnaces	105	2, 689, 650	25, 616
Total	307	5, 146, 972	16, 765

To indicate the progress made, these figures when compared with similar data for 1873 show that in ten years the average output has been greatly augmented in each of the branches, most notably in the furnaces using bituminous fuel.

The average output per furnace in 1873 *and in* 1883 *compared.*

Furnaces.	Number of furnaces in blast December 31, 1873.	Pig iron made in 1873.	Average output per furnace in 1873.	Augment average output in 1883 over that of 1873.
		Short tons.	*Short tons.*	*Short tons.*
Charcoal furnaces	190	577, 620	3, 040	3, 766
Anthracite furnaces	137	1, 312, 754	9, 582	6, 398
Bituminous-coal furnaces	83	977, 904	11, 782	13, 834
Total	410	2, 868, 278	6, 996	9, 769

A late discussion of blast-furnace capacity and production (*Journal of the United States Association of Charcoal Iron Workers*, 1884, Vol. V., pp. 217–228) shows that at no time since 1873 have over 63.7 per cent. of all the blast furnaces in the country been reported as in blast; and the proportion of active furnaces has been as low as 30 per cent. of the whole.

The largest percentage of active furnaces returned was 82.1, as shown by the record of anthracite furnaces in April, 1880; and the least proportion of anthracite furnaces in blast was 31.1 per cent., in September, 1876.

The bituminous furnaces show less variation than those using anthracite, the maximum percentage of the bituminous furnaces being 70.7, in April, 1881, and the minimum, 36.3, in September, 1876.

The returns for December 31, 1873, show 68.1 per cent. of the charcoal furnaces in operation, and those for April, 1877, exhibit but 20.2 per cent. in blast.

The growth of the pig-iron industry by periods of years shows that since 1810 the quantity of pig iron made increased practically threefold in each double decade; thus the total pig-iron production was:

Years.	Long tons.
1810	54,000
1830	165,000
1850	564,755
1870	1,665,179
1883	4,623,323

The last figures seem to indicate that the same geometrical progression is being continued.

That this augmented product was not due to an increased number of blast furnaces is evident, for at present there are but sixty-three more furnace plants than in 1872, when 2,548,214 long tons of iron were made, the total pig-iron product increasing in twelve years 81 per cent., while the number of blast furnaces is but 10 per cent. greater than in 1872 and 6 per cent. less than in 1881 (see "Mineral Resources of the United States, 1882," page 121).

Until 1840 practically all the iron made was smelted with charcoal, and up to 1855 more pig iron was produced with this fuel than with any other. But in 1855 the quantity of anthracite pig iron exceeded the product of the charcoal blast furnaces, and has ever since done so. It was, however, not until 1869 that more pig iron was made with bituminous fuel than with charcoal, and this prestige has since been continuously maintained. Anthracite pig iron was in advance until 1875, when the quantity produced with bituminous fuel was greater than that made with anthracite.

From 1856 to 1871, with the exceptions of the years 1857 and 1870, the quantity of anthracite pig iron made continuously exceeded the combined production of bituminous and charcoal pig iron. Nearly equal proportions of the total product were made with anthracite and bituminous fuels from 1872 to 1880, since which time the annual output of the bituminous furnaces has increased in greater ratio than that of those using anthracite; and in 1883 it was greater than the quantity made by the anthracite and charcoal furnaces combined.

From these statements an idea of mean capacities can be obtained, but the extremes which make up these averages are far removed from each other. Remarkable records have been made by individual plants in each branch of iron production, but ordinarily more attention is given to announcements of the output in a given time than of the fuel consumption; and when the latter is reduced notably the statement is too seldom appreciated in its true relations. It is not always the lowest fuel consumption which indicates the best management, for often one furnace may carry considerable more burden of ore and flux, with a given weight of fuel, than another, and yet show a greater consumption of fuel per ton of product by reason of the leanness or impurities of the ore used.

The output of an old-style cold-blast charcoal furnace, 9 feet in diameter at bosh and 28 feet high, was, as stated, from 4 to 6 tons of pig iron per day, the consumption of charcoal being from 150 to 225 bushels per ton. The paper on Mont Alto furnace work, to which reference has been made, gives the output of that furnace in 1883, with bosh diameter of 9½ feet and height of 44 feet, as averaging 25½ tons of cold-blast iron, on a consumption of 129 bushels of charcoal per ton of iron made.

When hot blast was employed the older furnaces of the above dimensions increased their product to from 8 to 10 tons per day; but improved appliances and management have latterly obtained 30 to 40 tons per day from furnaces of practically the same diameter of bosh, but with larger crucibles and greater height, and the fuel consumption has fallen to 100 bushels per ton. In larger and more modern plants of 11 feet diameter at bosh and 60 feet high, a product of 70 tons per day, and a fuel consumption of less than 85 bushels of charcoal per ton, have been attained.

Anthracite or bituminous furnaces were not operated cold-blast, but a comparison of results obtained from plants twenty years ago with those of the same size to-day shows that the output has practically doubled under more intelligent management; and furnaces 16 feet diameter and 55 feet high, which formerly made 30 tons of iron per day, now produce from 60 to 90 tons. Technical knowledge and the application of new improvements have done even more for bituminous furnaces, for in these the employment of coke with superheated blast, and the establishment of new plants, have given them advantages not possessed by others. Bituminous furnaces, which ten years ago became prominent because they made 80 tons per day, have now reached an output of over 300 tons per day.

So rapidly have the furnaces advanced in their product, and so marked has been the low fuel consumption per ton of iron made, that it is not deemed advisable to quote more exact figures of product in this paper than those above, for fear that they may be below actual results by the time the present report is printed. The consumption of less than 1 pound of mineral fuel to make 1 pound of pig iron has been attained at a number of works, but the average for all the furnaces will be greater than this amount—probably 1.4 pounds.

The modern blast furnace.—As intimated, many of the older plants, particularly those constructed to use charcoal or anthracite fuel, have been altered and improved; the dimensions have been enlarged, powerful steam machinery has been introduced, and larger hot-blast stoves and boilers have been added. The boshes have been steepened, so that the slopes at present vary from 1½ inches to 4 inches, instead of from 6 to 10 inches per foot as formerly, and large crucibles have taken the place of contracted ones. A majority of the newer plants have been located in the iron districts where bituminous coal is used, but a number of them have been constructed to employ anthracite and charcoal.

Reviewing what has been said heretofore, a modern blast-furnace structure may be described as a wrought-iron shell or casing, resting upon a wrought-iron mantle sustained by wrought or cast-iron columns of such height as to expose as much of the bosh as possible to the cooling action of the atmosphere.

The interior shape of the furnace approximates two frustra of cones placed base to base at the bosh, the two lesser diameters fixing the size of the bottom and the stock line; the variations are mainly in cylindrical portions for the crucible or prolongation of the bosh, in greater or less slope to the bosh and inwalls, and in the relative sizes of the greater and lesser diameters of the two ends of the frustra. The tunnel head is fitted with cup and cone, or bell and hopper, operated by a lever, and the charging opening is covered by a seal plate. Gas is withdrawn just below the hopper and conveyed in masonry flues to the "downcomer."

As a rule the slope of boshes is much steeper, the area at tuyere level and stock line proportionately greater, and the structures higher than formerly, the increased height being owing to raising the tuyeres, steepening the slope of boshes, and increasing the cubical contents of the shaft of the furnace in which ores are prepared for smelting. No American furnaces have, however, been carried to the extreme heights of some plants in Great Britain.

Thin walls of firebrick protected by water-cooled appliances take the place of thick stone masonry, and large tuyeres are employed. Volume rather than pressure of blast is recognized as the gauge for determining the proper operation of the plant.

Gas is brought from the top of the furnace by wrought-iron pipes or "downcomers," either to overhead iron or underground masonry flues, which connect with burners at the hot ovens and boilers, and the results of combustion are carried to high-draft stacks or chimneys, generally constructed of wrought iron and lined with firebrick.

Washing, or rather condensing, the furnace gases by means of jets or pans of water placed in the "downcomers," has met with some favor from managers, because thereby so much of the flue dust is kept out of the connections.

Duplicate iron-pipe stoves or regenerative firebrick stoves are employed for heating the blast, but few furnaces have an excess of either form. Ordinarily two iron-pipe or three regenerative stoves are connected to a furnace. Four of the latter would secure greater uniformity of temperature, and not less than this number is advisable. The pipes conveying the heated air are either lined inside or protected on the outside with non-conducting materials, and tuyere fixtures are, as far as is practicable, similarly treated.

A substantial brick building contains several blowing engines of the vertical type, with receivers for taking up the oscillations due to the strokes of the engines, and generally also the requisite pumping machinery, which (owing to the cooling appliances requiring considerable quantities of water) are important features in the machinery of a blast furnace. Large stock houses of brick or iron, in which railroad tracks are carried on trestles over bins, protect the raw material and cover the "fillers" while loading the barrows of ore, flux, or fuel, which are then carried to the tunnel head by vertical steam hoists with double cages. Brick or iron casting houses protect the workmen who tap the furnace, and railroad tracks run alongside or into them, to carry away the cinder or pig iron. Some of the buildings of the newer blast furnaces are quite attractive in design and substantial in construction.

Various methods of handling and dumping cinder by railroad cars are in use. The hot cinder is run from cars on to heaps or it is allowed to flow in successive thin layers, which, when cooled, are broken by bars into road metaling. Slag is also granulated by injecting a stream of water under pressure against a falling stream of fluid cinder, and it is blown with steam into fine threads commercially known as "mineral wool." The necessity of caring for large masses of slag or cinder has proved an item of considerable expense at a number of blast furhaces, and the matter of dump room must be considered in connection with the question of supplies of fuel, ore, flux, and water, or accessibility to markets, when locating a new plant.

The tendency has been to construct large furnaces in batteries or sets, the plant being equipped with ample blowing machinery, boilers, blast-heating apparatus, water supply, etc., so arranged that all can be concentrated on one furnace or any portion of the plant used for either furnace.

The neat, symmetrical furnace stacks, chimneys, and hot-blast stoves; the substantial casting, stock, engine, and boiler houses, the absence of flame from the tunnel head, the puffing of small locomotives drawing ore, flux, fuel, pig iron, or cinder, and the quantity of material thus handled, present a strange contrast to the charcoal furnace of fifty years ago. The massive stone stack, from which the flame constantly rose and fell with the wheezing of the blast, and around which centered the entire interest of a community dependent upon its action, the battery of ore carts and charcoal wagons, with their motive power represented by a hundred braying mules, and the Arcadian simplicity of all the surroundings (save at the mansion house), were characteristics of the olden time furnace.

Few instances of progress can be mentioned more notable than is exhibited by comparison of "the old charcoal blast furnace" and "the modern blast furnace."

[A paper by Mr. P. Barnes, on "The Present Technical Condition of the Steel Industry of the United States," prepared for this volume, has been omitted for lack of space, and is published separately as Bulletin No. 25 of the United States Geological Survey.]

GOLD AND SILVER.

The Mint statistics.—Hon. Horatio C. Burchard, late Director of the Mint, has made estimates of the production of the precious metals in the United States, and his results (for the last four years) are accepted as authoritative in this report, no provision having yet been made for the collection of gold and silver statistics by this office. A number of other estimates, showing greater or less discrepancies, have been published. A table is appended, showing Mr. Burchard's estimates, by States, for the period 1881 to 1884, inclusive. It will be seen from these figures that the total production has been very steady of late; but that the gold output has declined somewhat while the silver yield has slightly increased. The decline in the production of gold has been mainly due to the depression of hydraulic mining in California. The annual output of the two "precious" metals in the United States is about the same in value as that of the pig iron at present prices, but far below the value of the coal production. In 1883 the production fell short of the yield in 1882 by $2,500,000 gold and $600,000 silver. In 1884 the gold production increased $800,000 and the silver production increased $2,600,000, as compared with 1883.

Production of gold and silver in the United States during the calendar years 1881 *to* 1884 *inclusive.*

States and Territories.	1881.			1882.		
	Gold.	Silver.	Total.	Gold.	Silver.	Total.
Alaska	$15, 000	....	$15, 000	$150, 000	....	$150, 000
Arizona	1, 060, 000	$7, 300, 000	8, 360, 000	1, 065, 000	$7, 500, 000	8, 565, 000
California	18, 200, 000	750, 000	18, 950, 000	16, 800, 000	845, 000	17, 645, 000
Colorado	3, 300, 000	17, 160, 000	20, 460, 000	3, 360, 000	16, 500, 000	19, 860, 000
Dakota	4, 000, 000	70, 000	4, 070, 000	3, 300, 000	175, 000	3, 475, 000
Georgia	125, 000	....	125, 000	250, 000	....	250, 000
Idaho	1, 700, 000	1, 300, 000	3, 000, 000	1, 500, 000	2, 000, 000	3, 500, 000
Maine	....	5, 000	5, 000	....	....	....
Montana	2, 330, 000	2, 630, 000	4, 960, 000	2, 550, 000	4, 370, 000	6, 920, 000
Nevada	2, 250, 000	7, 060, 000	9, 310, 000	2, 000, 000	6, 750, 000	8, 750, 000
New Mexico	185, 000	275, 000	460, 000	150, 000	1, 800, 000	1, 950, 000
North Carolina	115, 000	....	115, 000	190, 000	25, 000	215, 000
Oregon	1, 100, 000	50, 000	1, 150, 000	830, 000	35, 000	865, 000
South Carolina	35, 000	....	35, 000	25, 000	....	25, 000
Tennessee	5, 000	....	5, 000	....	....	....
Utah	145, 000	6, 400, 000	6, 545, 000	190, 000	6, 800, 000	6, 990, 000
Virginia	10, 000	....	10, 000	15, 000	....	15, 000
Washington	120, 000	....	120, 000	120, 000	....	120, 000
Wyoming	5, 000	....	5, 000	5, 000	....	5, 000
Total	34, 700, 000	43, 000, 000	77, 700, 000	32, 500, 000	46, 800, 000	79, 300, 000

Production of gold and silver in the United States, &c.—Continued.

States and Territories.	1883.			1884.		
	Gold.	Silver.	Total.	Gold.	Silver.	Total.
Alaska	$300, 000	....	$300, 000	$200, 000	....	$200, 000
Arizona	950, 000	$5, 200, 000	6, 150, 000	930, 000	$4, 500, 000	5, 430, 000
California	14, 120, 000	1, 460, 000	15, 580, 000	13, 600, 000	3, 000, 000	16, 600, 000
Colorado	4, 100, 000	17, 370, 000	21, 470, 000	4, 250, 000	16, 000, 000	20, 250. 000
Dakota	3, 200, 000	150, 000	3, 350, 000	3, 300, 000	150, 000	3, 450, 000
Georgia	199, 000	1, 000	200, 000	137, 000	....	137, 000
Idaho	1, 400, 000	2, 100, 000	3, 500, 000	1, 250, 000	2, 720, 000	3, 970, 000
Montana	1, 800, 000	6, 000, 000	7, 800, 000	2, 170, 000	7, 000, 000	9, 170, 000
Nevada	2, 520, 000	5, 430, 000	7, 950, 000	3, 500, 000	5, 600, 000	9, 100, 000
New Mexico	280, 000	2, 845, 000	3, 125, 000	300, 000	3, 000, 000	3, 300, 000
North Carolina	167, 000	3, 000	170, 000	157, 000	3, 500	160, 500
Oregon	660, 000	20, 000	680, 000	660, 000	20, 000	680, 000
South Carolina	56, 500	500	57, 000	57, 000	500	57, 500
Utah	140, 000	5, 620, 000	5, 760, 000	120, 000	6, 800, 000	6, 920, 000
Virginia	6, 000	....	6, 000	2, 000	....	2, 000
Washington	80, 000	500	80, 500	85, 000	1, 000	86, 000
Wyoming	4, 000	....	4, 000	6, 000	....	6, 000
Other	17, 500	....	17, 500	76, 000	5, 000	81, 000
Total	30, 000, 000	46, 200, 000	76, 200, 000	30, 800, 000	48, 800, 000	79, 600, 000

Rank of the States and Territories in the production of gold and silver in 1883.

Gold.	Silver.	Total.
1. California.	1. Colorado.	1. Colorado.
2. Colorado.	2. Montana.	2. California.
3. Dakota.	3. Utah.	3. Nevada.
4. Nevada.	4. Nevada.	4. Montana.
5. Montana.	5. Arizona.	5. Arizona.
6. Idaho.	6. New Mexico.	6. Utah.
7. Arizona.	7. Idaho.	7. Idaho.
8. Oregon.	8. California.	8. Dakota.
9. Alaska.	9. Dakota.	9. New Mexico.
10. New Mexico.	10. Oregon.	10. Oregon.
11. Georgia.	11. North Carolina.	11. Alaska.
12. North Carolina.	12. Georgia.	12. Georgia.
13. Utah.	13. Washington. South Carolina.	13. North Carolina.
14. Washington.		14. Washington.
15. South Carolina.		15. South Carolina.
16. "Other."		16. "Other."
17. Virginia.		17. Virginia.
18. Wyoming.		18. Wyoming.

Rank of the States and Territories in the production of gold and silver in 1884.

Gold.	Silver.	Total.
1. California.	1. Colorado.	1. Colorado.
2. Colorado.	2. Montana.	2. California.
3. Nevada.	3. Utah.	3. Montana.
4. Dakota.	4. Nevada.	4. Nevada.
5. Montana.	5. Arizona.	5. Utah.
6. Idaho.	6. California. New Mexico.	6. Arizona.
7. Arizona.		7. Idaho.
8. Oregon.	8. Idaho.	8. Dakota.
9. New Mexico.	9. Dakota.	9. New Mexico.
10. Alaska.	10. Oregon.	10. Oregon.
11. North Carolina.	11. "Other."	11. Alaska.
12. Georgia.	12. North Carolina.	12. North Carolina.
13. Utah.	13. Washington.	13. Georgia.
14. Washington.	14. South Carolina.	14. Washington.
15. "Other."		15. "Other."
16. South Carolina.		16. South Carolina.
17. Wyoming.		17. Wyoming.
18. Virginia.		18. Virginia.

Mr. Valentine's statistics for 1883.—Mr. J. J. Valentine, vice-president and general manager of Wells, Fargo & Co., has prepared the following statement of the bullion product of the States and Territories west of the Missouri river (including British Columbia, and receipts by express from the west coast of Mexico) in 1883, based upon the express and freight returns. This table includes the value of lead and copper, as well as gold and silver.

Bullion product of the States and Territories west of the Missouri river in 1883, *including value of base bullion (lead and copper), and also including the partial products of British Columbia and the west coast of Mexico.*

[Estimated by Mr. J. J. Valentine.]

States and Territories.	Gold dust and bullion by express.	Gold dust and bullion by other conveyances.	Silver bullion by express.	Ores and base bullion by freight.	Total.
California	$13, 182, 188	$659, 109	$1, 171, 748	$660, 269	$15, 673, 314
Nevada	1, 097, 595		5, 924, 252	1, 749, 774	8, 771, 621
Oregon	387, 927	193, 963	11, 090		592, 980
Washington	42, 117	21, 058	351		63, 526
Alaska	85, 000	20, 000			105, 000
Idaho	1, 077, 985	215, 597	692, 545	1, 819, 700	3, 805, 827
Montana	2, 380, 000	119, 000	4, 900, 000	2, 480, 000	9, 879, 000
Utah	27, 036	4, 134	2, 398, 627	4, 587, 885	7, 017, 682
Colorado	2, 341, 692		4, 434, 444	17, 533, 864	24, 310, 000
New Mexico	123, 642	50, 000	1, 190, 977	2, 048, 900	3, 413, 519
Arizona	340, 686	150, 000	4, 147, 427	3, 545, 630	8, 183, 743
Dakota	2, 448, 000	245, 000	130, 000		2, 823, 000
Total	23, 533, 868	1, 677, 861	25, 001, 461	34, 426, 022	84, 639, 212
Mexico (west coast)	767, 836		3, 870, 548	384, 000	5, 022, 384
British Columbia	521, 613	130, 403			652, 016
Total	24, 823, 317	1, 808, 264	28, 872, 009	34, 810, 022	90, 313, 612

The gross yield for 1883, shown in the foregoing table, segregated, was approximately as follows:

	Per cent.	Value.
Gold	32. 36	$29, 236, 492
Silver	52. 30	47, 229, 649
Copper	6. 30	5, 683, 921
Lead	9. 04	8, 163, 550
		90, 313, 612

Mr. Valentine makes the following comparison between his returns for 1883 and 1882: "California shows a decrease in gold of $1,629,028, and an increase of silver of $969,844. Nevada shows a falling off of $1,591,755. The Comstock shows an increase of $392,468; but there is a decrease in the product of Eureka district of $1,419,124. With the exception of Montana and Idaho, there is a decrease in the product of the other States and Territories. The facilities afforded for the transportation of bullion, ores, and base metals, by the extension of railroads into the mining districts, increase the difficulty of verifying the reports of the products from several important localities; and the general tendency is to exaggeration when the actual values are not obtainable from authentic sources; but the aggregate result, as shown herein, we think may be relied on with reasonable confidence as approximately correct."

Mr. Valentine's statistics for 1884.—Mr. Valentine's estimate for 1884 is as follows:

Bullion product of the States and Territories west of the Missouri river in 1884, *including value of base bullion (lead and copper), and also including the partial products of British Columbia and the west coast of Mexico.*

[Estimated by Mr. J. J. Valentine.]

States and Territories.	Gold dust and bullion by express.	Gold dust and bullion by other conveyances.	Silver bullion by express.	Ores and base bullion by freight.	Total.
California	$12,282,471	$614,123	$1,504,705	$871,689	$15,272,988
Nevada	1,527,859		5,905,304	1,455,776	8,888,939
Oregon	368,315	184,157	2,695		555,167
Washington	45,964	22,982	1,179		70,125
Alaska	35,014	80,000			115,014
Idaho	1,010,077	150,000	812,100	1,570,000	3,542,177
Montana	1,875,000		6,175,000	3,812,000	11,862,000
Utah	31,501	4,134	2,657,054	4,697,147	7,389,836
Colorado	2,575,861		4,877,888	12,780,000	20,233,749
New Mexico	157,688	60,000	906,248	2,536,678	3,660,614
Arizona	360,791	100,000	3,139,628	3,455,960	7,056,379
Dakota	2,726,847	150,000	110,000		2,986,847
Total	22,997,388	1,365,396	26,091,801	31,179,250	81,633,835
Mexico (west coast)	285,256		2,257,144	12,000	2,554,400
British Columbia	647,719	140,000			787,719
Total	23,930,363	1,505,396	28,348,945	31,191,250	84,975,954

The values of the gold, silver, copper, and lead, segregated, were:

	Per cent.	Value.
Gold	30.90	$26,256,542
Silver	53.90	45,799,069
Copper	7.16	6,086,252
Lead	8.04	6,834,091
		84,975,954

Mr. Valentine says: "California shows a decrease in gold of $944,703, and an increase in silver of $513,597. In Nevada, the Comstock shows an increase of $1,668,524; Eureka district shows a decrease of $123,152; in the total product of the State there is an increase of $117,318; Montana shows a considerable increase; Colorado and Arizona a decrease from the production of 1883."

Mr. Valentine's statistics for fifteen years.—The value of the gold and silver production of the States and Territories west of the Missouri river since 1870, according to Mr. Valentine, is shown in the following table, from which the production of British Columbia and the shipments from the west coast of Mexico, and the values of copper and lead, have been excluded:

Mr. Valentine's estimates of the production of gold and silver in the States and Territories west of the Missouri river from 1870 *to* 1884 *inclusive.*

Years.	Gold.	Silver.	Total.
1870	$33,750,000	$17,320,000	$51,070,000
1871	34,398,000	19,286,000	53,684,000
1872	38,177,395	19,924,429	58,101,824
1873	39,206,558	27,483,302	66,689,860
1874	38,466,488	29,699,122	68,165,610
1875	39,968,194	31,635,239	71,603,433
1876	42,886,935	39,292,924	82,179,859
1877	44,880,223	45,846,109	90,726,332
1878	37,576,030	37,248,137	74,824,167
1879	31,420,262	37,032,857	68,453,119
1880	32,559,067	38,033,055	70,592,122
1881	30,653,959	42,987,613	73,641,572
1882	29,011,318	48,133,039	77,144,357
1883	27,816,640	42,975,101	70,791,741
1884	25,183,567	43,529,925	68,713,492

To compare the results arrived at by the two different methods of estimation it is found that Mr. Burchard's figures for 1883 exceed Mr. Valentine's by $2,183,360 gold, $3,224,899 silver, and $5,408,259 in the total. For 1884 the apparent difference is $5,616,433 gold, $4,270,075 silver, and $10,886,508 total. The Mint returns, however, include the production of the States east of the Missouri river, while Mr. Valentine's do not. The silver product as estimated by Mr. Burchard is quoted at the full coining value, while possibly some of the express and freight returns are given at the market rate for silver.

Comparison of estimates for 1883.

	Gold.	Silver.	Total.
Mr. Burchard's estimate	$30,000,000	$46,200,000	$76,200,000
Mr. Valentine's estimate	27,816,640	42,975,101	70,791,741
Difference	2,183,360	3,224,899	5,408,259

Comparison of estimates for 1884.

	Gold.	Silver.	Total.
Mr. Burchard's estimate	$30,800,000	$48,800,000	$79,600,000
Mr. Valentine's estimate	25,183,567	43,529,925	68,713,492
Difference	5,616,433	4,270,075	10,886,508

Total output to date.—As nearly as can now be ascertained the total production of gold in the United States since 1804 has been $1,676,914,670, and of silver, $669,683,217; total, $2,346,597,887.

Production of gold and silver in the United States to December 31, 1884.

Periods.	Gold.	Silver.	Total.
Output of the Southern States from 1804 to the discovery of gold in California in 1848 (based on estimates of Prof. J. D. Whitney)	$13,243,475		$13,243,475
Product from 1848 to 1879, inclusive, by fiscal years	1,484,041,532	$422,722,260	1,906,763,792
Fiscal year ending June 30, 1880 (census figures, covering a period one month earlier, assumed)	33,379,663	41,110,957	74,490,620
July 1, 1880, to December 31, 1880 (estimated on the basis of half the product of the fiscal year 1881, as reported by Hon. Horatio C. Burchard, Director of the Mint)	18,250,000	21,050,000	39,300,000
Calendar years 1881 to 1884, inclusive (as reported by Hon. Horatio C. Burchard, Director of the Mint)	128,000,000	184,800,000	312,800,000
Total product of the United States to close of 1884	1,676,914,670	669,683,217	2,346,597,887

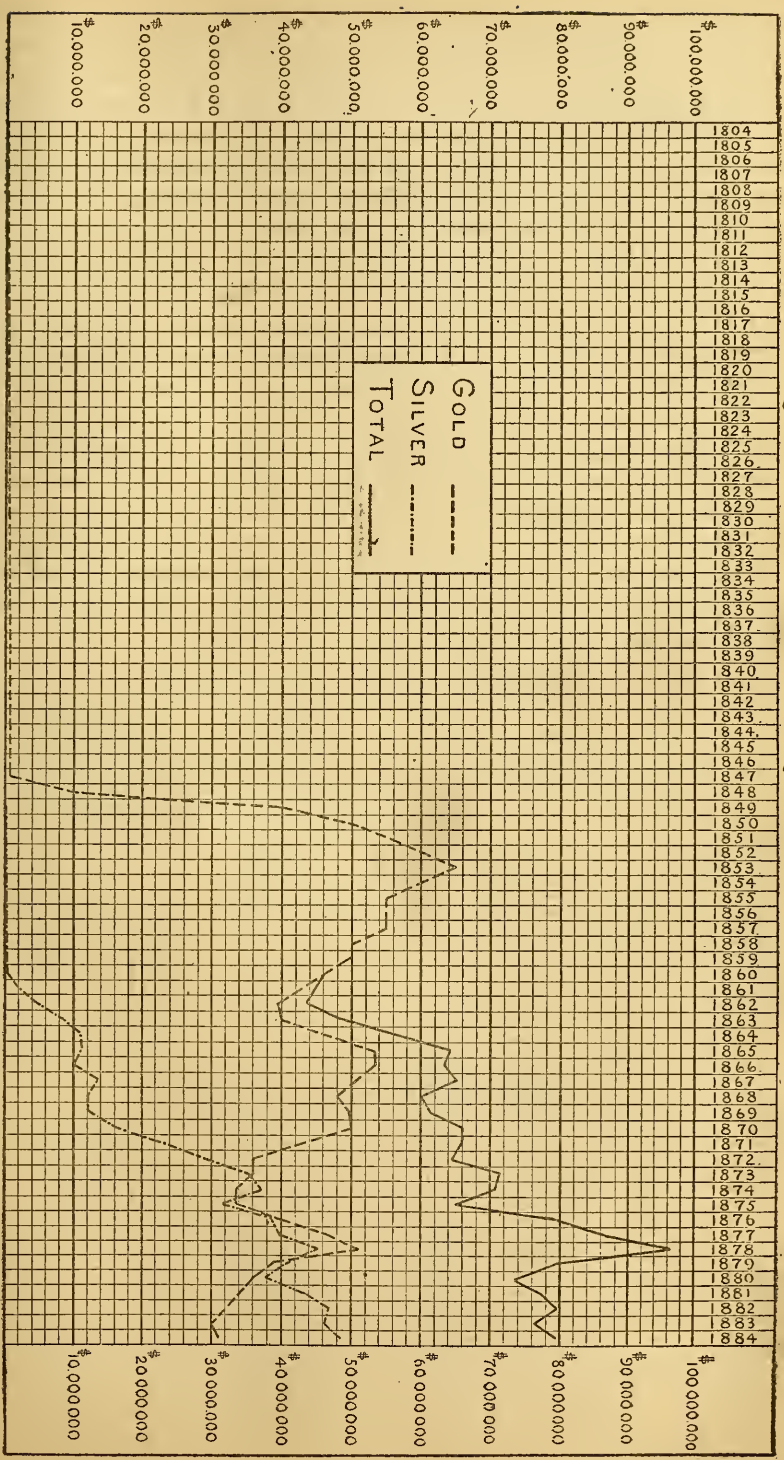

FIG. 2.—PRODUCTION OF GOLD AND SILVER IN THE UNITED STATES TO DECEMBER 31, 1884.

Profits in precious-metal mining.—In the first report of this series it was said: "The production of gold and silver, like that of other commodities, is of course not one of clear profit. Indeed, a saying that it costs $1 in coin to produce $1 in bullion has gained more or less credit; and though this opinion has been abundantly shown to be unfounded, and while also any attempt to estimate the profit gained to the country by the mining of the precious metals is mere guesswork, it is still quite probable that $500,000,000 of the gross total has been net profit." This opinion was based upon a consideration of the large profits which attended the earlier mining enterprises. The margin of profit, especially in gold mining, is undoubtedly smaller now than formerly. It is impossible to ascertain the actual returns to investors, owing to the large number of mines not operated by corporations and from which no reports are published, but the following statement has been made from the published returns for 1883 and 1884, from which it appears that in these years the reported dividends were not greatly in excess of the reported assessments. Still it must be remembered that the returns are very imperfect, and that, for obvious reasons, the published announcements of assessments are proportionately nearer the truth than the reports of dividends, while a vast number of smaller unincorporated mines, which could not be operated at a loss, are not represented.

Assessments and dividends reported in 1883.

States and Territories	Assessments.	Dividends.		
	Amount.	Mines.	Number of dividends.	Amount.
Alaska	$20,250			
Arizona	165,500	3	14	$600,000
California	1,196,044	13	56	1,004,976
Colorado		17	31	1,200,750
Dakota	10,000	3	18	645,500
Georgia		1	6	24,000
Idaho		4	16	85,000
Montana		5	39	513,824
Nevada	4,244,490	6	25	584,000
New Mexico		1	5	500,000
Utah	52,000	5	13	1,582,000
Total	5,688,284	58	223	6,740,050

Assessments and dividends reported in 1884.

States and Territories.	Assessments.	Dividends.		
	Amount.	Mines.	Number of dividends.	Amount.
Alaska	$3,400			
Arizona	137,000	3	4	$117,500
California	768,350	13	69	1,850,948
Colorado		14	34	1,419,000
Dakota		3	34	578,250
Montana		8	38	922,000
Nevada	3,632,950	5	18	201,500
New Mexico		2	3	190,000
Utah	68,000	5	24	2,257,500
Vermont		1	3	31,000
Total	4,609,700	54	227	7,567,698

Consumption in the arts.—In 1883 the value of the gold and silver consumed in the United States in the manufacture of chemicals, watches, jewelry, instruments, plate, etc., and in repairs, was stated at $14,223,448 gold, and $5,392,777 silver; total, $19,616,225. In 1884 the corresponding amounts were estimated at $14,500,000 gold, $5,500,000 silver, and $20,000,000 total. This consumption has attracted much attention, in view of the heavy draft upon the coin circulation of this country, and in consideration of the similar absorption of the precious metals, especially of gold, which is going on abroad. If the figures are correct, the apparent consumption of gold in the arts is nearly one-half of the total gold product. It should be remembered, however, that a considerable portion of the gold and silver temporarily absorbed in this way returns again into circulation as coin, and that of this total consumption only about one-half is domestic bullion produced in the same year. Thus in 1884 the industrial consumption of new bullion, produced by mines of the United States in that year, is estimated by Mr. Burchard to have been only $6,000,000 gold, $4,500,000 silver, and $10,500,000 total.

The world's production of gold and silver.—The annexed table, compiled by Mr. Burchard, shows the total output of the precious metals in the world, as nearly as can be estimated. For several of the countries there are no official figures, and in some cases it has been necessary to repeat earlier statistics, in the absence of fresh reports. The yield of gold appears to be steadily declining, while that of silver is increasing. The annual contribution of the United States to the world's stock of the precious metals is now about one-third of the total gold supply and about two-fifths of the silver.

The world's production of gold and silver.

Countries.	1881.			
	Gold.		Silver.	
	Kilos.		*Kilos.*	
United States	52, 212	$34, 700, 000	1, 034, 649	$43, 000, 000
Russia	36, 671	24, 371, 343	7, 992	332, 198
Australia	46, 178	30, 690, 000	3, 970	164, 983
Mexico	1, 292	858, 909	665, 918	27, 675, 540
Germany	350	232, 610	186, 990	7, 771, 304
Austria-Hungary	1, 867	1, 240, 808	31, 359	1, 303, 280
Sweden	1	665	1, 176	48, 875
Norway	....	....	4, 812	199, 987
Italy	109	72, 375	432	17, 949
Spain	....	....	74, 500	3, 096, 220
Turkey	7	4, 918	1, 719	71, 441
Argentine Republic	118	78, 546	10, 109	420, 225
Colombia	6, 019	4, 000, 000	24, 057	1. 000, 000
Bolivia	109	72, 375	264, 677	11, 000, 000
Chili	194	128, 869	122, 275	5, 081, 747
Brazil	1, 116	741, 694	....	....
Japan	702	466, 548	22, 046	916, 400
Africa	3, 000	1, 993, 800	....	....
Venezuela	3, 423	2, 274, 692	....	....
Canada	1, 648	1, 094, 926	1, 641	68, 205
France	....	....	....	....
Total	155, 016	103, 023, 078	2, 458, 322	102, 168, 354

The world's production of gold and silver—Continued.

Countries.	1882.			
	Gold.		Silver.	
	Kilos.		*Kilos.*	
United States	48, 902	$32, 500, 000	1, 126, 083	$46, 800, 000
Russia	35, 913	23, 867, 935	7, 781	323, 427
Australia	43, 550	28, 943, 217	2, 475	102, 878
Mexico	1, 409	936, 223	703, 508	29, 237, 798
Germany	376	249, 890	214, 982	8, 934, 652
Austria-Hungary	1, 580	1, 050, 068	47, 118	1, 958, 224
Sweden	17	11, 298	1, 500	62, 350
Norway	....	....	5, 893	244, 954
Italy	109	72, 375	432	17, 949
Spain	....	....	74, 500	3, 096, 220
Turkey	10	6, 646	2, 164	89, 916
Argentine Republic	118	78, 546	10, 109	420, 225
Colombia	5, 802	3, 856, 000	18, 283	760, 000
Bolivia	109	72, 375	264, 677	11, 000, 000
Chili	245	163, 000	128, 106	5, 325, 000
Brazil	1, 116	741, 694	....	....
Japan	702	466, 548	22. 046	916, 400
Africa	3, 000	1, 993, 800	....	....
Venezuela	3, 904	2, 595, 077	....	....
Canada	1, 648	1, 094, 926	1, 641	68, 205
France	....	....	14, 291	594, 053
Total	148, 510	98, 699, 588	2, 645, 589	109, 952, 251

Countries.	1883.			
	Gold.		Silver.	
	Kilos.		*Kilos.*	
United States	45, 140	$30, 000, 000	1, 111, 457	$46, 200, 000
Russia	35, 913	23, 867, 935	7, 781	323, 427
Australia	39, 873	26, 500, 000	1, 924	80, 000
Mexico	1, 438	955, 639	711, 347	29, 568, 576
Germany	457	303, 722	230, 694	9, 589, 300
Austria-Hungary	1, 638	1, 088, 615	48, 708	2, 024, 645
Sweden	37	24, 590	1, 583	65, 800
Norway	....	....	5, 645	234, 645
Italy	109	72, 375	432	17, 945
Spain	....	....	74, 500	3, 096, 220
Turkey	10	6, 646	2, 164	89, 916
Argentine Republic	118	78, 546	10, 109	420, 225
Colombia	5, 802	3,856, 000	18, 283	760, 000
Bolivia	109	72, 375	384, 923	16, 000, 000
Chili	245	163, 000	128, 106	5, 325, 000
Brazil	952	632, 520	....	....
Japan	181	120, 080	8, 488	353, 825
Africa	3, 000	1, 993, 800	....	....
Venezuela	5, 022	3, 338, 058	....	....
Canada	1, 435	954, 000	1. 641	68, 205
France	....	....	....	....
Total	141, 479	94, 027, 901	2, 747, 785	114, 217, 733

Imports of gold and silver, 1868 *to* 1884 *inclusive*.

Fiscal years ending June 30—	Gold.			Silver.	
	Dust. (*a*)	Bullion.	Coin.	Bullion.	Coin.
1868	....	$1, 909, 503	$6, 558, 602	$151, 238	$5, 304, 835
1869	....	890, 064	13, 240, 191	54, 267	5, 622, 548
1870	....	697, 904	11, 452, 414	161, 932	14. 217, 406
1871	....	1, 177, 387	5, 704, 298	69, 836	11, 591, 875
1872	$258, 329	1, 101, 617	7, 339, 572	405, 631	4, 647, 034
1873	7, 771	1, 549, 899	7, 092, 011	476, 608	12, 318, 911
1874	20, 842	1, 349, 346	18, 089, 155	830, 639	8, 153, 087
1875	15, 222	1, 562, 767	12, 018, 537	1, 294, 763	5, 913, 474
1876	28, 802	1, 167, 102	6, 596, 692	1, 057, 377	6, 885, 795
1877	85, 858	2, 032, 997	24, 131, 925	4, 693, 605	9, 8[illegible]9, 666
1878	17, 602	1, 955, 005	11, 365, 656	6, 971, 849	9, 512, 704
1879	17, 949	1, 275, 749	4, 373, 168	2, 424, 675	12, 203, 871
1880	883, 690	19, 453, 755	60, 420, 951	1, 981, 425	10, 294, 489
1881	697, 467	30, 301, 452	69, 032, 340	2, 303, 472	8, 240, 766
1882	647, 551	8, 758, 502	24, 971, 001	2, 121, 833	5, 973, 603
1883	....	3, 334, 708	14, 399, 441	2, 475, 968	8, 279, 274
1884	....	4, 997, 571	17, 833, 746	2, 910, 451	11, 684, 494

a In 1868–1871, 1883, and 1884 included under head of gold bullion.

Exports of gold and silver of domestic production, 1851 *to* 1884 *inclusive*.

Fiscal years ending June 30—	Gold and silver coin. (*b*)	Gold.		Silver.	
		Bullion.	Coin.	Bullion.	Coin.
1851	$18, 069, 580	....	....	....	....
1852	37, 437, 837	....	....	....	....
1853	23, 548, 535	....	....	....	....
1854	38, 062, 570	....	....	....	....
1855	19, 842, 423	$34, 114, 995	....	....	....
1856	15, 458, 333	28, 689, 946	....	....	....
1857	28, 777, 372	31, 300, 980	....	....	....
1858	19, 474, 040	22, 933, 206	....	....	....
1859	24, 172, 442	33, 329, 863	....	....	....
1860	26, 033, 678	30, 913, 173	....	....	....
1861	10, 488, 590	13, 311, 280	....	....	....
1862	....	13, 267, 739	$17, 776, 912	....	....
1863	44, 608, 529	11, 385, 033	....	....	....
1864	....	10, 985, 703	86, 148, 921	$836, 387	$2, 502, 551
1865	....	21, 145, 055	35, 413, 651	6, 311, 986	1, 747, 432
1866	....	20, 731, 473	49, 395, 993	10, 832, 849	1, 683, 059
1867	....	13, 867, 641	22, 362, 035	15, 853, 530	2, 892, 990
1868	....	23, 841, 155	44, 390, 003	12, 978, 311	2, 536, 506
1869	....	13, 584, 407	14, 858, 369	13, 573, 427	899, 763
1870	....	15, 812, 108	12, 768, 501	11, 748, 864	3, 554, 329
1871	....	9, 089, 959	55, 491, 719	17, 285, 916	2, 535, 765
1872	....	7, 986, 145	40, 391, 357	22, 729, 657	1, 691, 081
1873	....	8, 810, 175	35, 661, 863	27, 759, 066	1, 674, 442
1874	....	3, 878, 543	28, 766, 943	22, 498, 782	4, 555, 418
1875	....	2, 233, 775	59, 309, 770	17, 197, 914	5, 115, 670
1876	....	1, 888, 896	27, 542, 861	15, 240, 344	5, 366, 590
1877	....	1, 084, 536	21, 274, 565	11, 482, 894	9, 292, 743
1878	....	205, 319	6, 427, 251	15, 035, 045	5, 394, 270
1879	....	24, 774	4, 120, 311	11, 883, 064	1, 526, 886
1880	....	87, 066	1, 687, 973	6, 912, 864	659, 990
1881	....	84, 943	1, 741, 364	11, 852, 995	547, 642
1882	....	1, 598, 336	29, 805, 289	11, 653, 547	423, 099
1883	....	4, 118, 455	4, 802, 454	12, 551, 378	150, 894
1884	....	23, 052, 183	12, 242, 021	14, 241, 050	690, 381

b In 1862 and 1864–1884 segregated, appearing in the other columns.

COPPER.

THE COPPER INDUSTRY OF THE UNITED STATES.

By C. Kirchhoff, Jr.

The years 1883 and 1884 have been very trying for the copper-mining and allied industries in the United States. In addition to the great influence upon them of the continued depression in all branches of business in this country, they have passed through an era of complete revolution of the conditions which have affected them during the past decades. The indications of the years 1881 and 1882 have been fulfilled, and from a spirited competition for the home markets the different copper-producing districts of the United States have entered upon a struggle for existence with the makers of the entire world. That contest has not yet ended, and it is a question which has been seriously discussed *pro* and *con* whether the fiercest moments of the fray have yet passed or not. In some respects our producers have been at a great advantage, in others they have struggled against adverse circumstances. The general effect of the sharp competition in all parts of the world has been the usual one of causing an increase in output, the stronger concerns adding to their yield greater quantities than the amounts of metal withdrawn from the supply by the closing of weaker mines, so that the net result has been quite a general increase in the production. The beginning of periods of depression usually causes mines that have been fairly prosperous for years to add to plant. They hope thus to make up for the falling off in the net returns due to lower prices per pound by forcing down general expenses per unit through a larger output, by scaling cost in every way, by reducing wages, and by taking advantage of the lower prices of raw materials and supplies caused by the general depression. Before a mine is closed down, the force disorganized, and the capital invested in it practically abandoned for at least an indefinite period, its reserves are exhausted, all dead work is suspended, and repairs and renewals of plant are neglected. Work is continued, particularly in the case of joint-stock enterprises, until all appeals to the stockholders fail to procure additional funds, and credit is exhausted. The history of mining has taught this over and over again, and the course of affairs, for instance, in the Lake Superior district during the past two years, has abundantly confirmed it. So far as it is possible to do so at a distance, we can trace the same causes at work in other countries through the reports of public companies. Unfortunately, in the case of Chili the fact that the mines are largely in the hands of private firms and families makes it difficult to follow their affairs.

While on the one hand declining prices have driven many mines to greater output, they have on the other hand effectually restricted the development of new enterprises. Those new ventures, and there were many of them, which had not yet been planted on a solid foundation have been forced to suspension or collapse, and nearly all efforts to raise the capital for new enterprises have failed. It is even a question which those interested in many American copper mines may well seriously debate, whether or not it would not be wiser to allow known large reserves of ore in their mines to remain untouched rather than exhaust them without reaping an adequate reward. This may be particularly urged where the deposits themselves are of an uncertain character, where the ore may be expected to change in character in depth in an unfavorable manner, where railroad communications are poor, fuel is excessively costly, or labor still commands exceptionally high figures.

In the face of all the discouraging circumstances of the past two years the United States has forged ahead to the position of the greatest copper producer of the world, and now occupies a leading rank as a contributor of raw material to its markets. This exuberant production at a time of general depression has no doubt reacted directly upon values, and the heavy output of this country is chiefly responsible for the decline of prices. It has been repeatedly urged, not alone abroad, but also by some of our producers, that the strenuous efforts made to swell the product were suicidal; that by an understanding among the leading mines in principal districts the output could be kept in hand, so that the net returns from the sale of smaller quantities at better prices would be as good, if not better, than those now realized. Even preliminary steps taken in this direction have shown that there is no harmony of opinion on the subject. The conviction seems to have been reached by the managers of the largest mines throughout the country that as newcomers in the world's market, on the footing of regular contributors to it, our copper mines must be the aggressors. They are unflinchingly meeting the market and will hold their position in it until either a closing down of the weaker mines in all parts of the world or the long-expected rapid development of consumption overtakes the production and makes an advance in price possible.

American copper goes abroad now in the form of ore, of matte, of black copper, of refined metal, and of electrolytic copper, every important producing region participating in the movement. It is to be regretted that we have not, during the past two years, made any substantial progress in placing the metal in foreign markets in a manufactured form. In the earlier stages of manufacture in our rolling mills rule of thumb reigns supreme, and the practice in mixing alloys and in melting is spoken of as very crude by men of unquestioned authority. It is in the subsequent mechanical process of shaping the metal, in the taste shown in the make-up of the goods, and in their exceptionally high quality, that American rolling mills and brass and bronze manufactories are said by experts to be far in advance of foreign rivals. Our own producers look with some impatience to the time when the home sales will be enlarged by a demand for raw material for manufactures to be exported, which would go hand in hand with lower prices for manufactured goods in this country, and therefore lead to an expanded home consumption. It is not likely that any steps will be taken in this direction until manufacturers feel convinced, first, that the present abundant production is not a passing phase, and secondly, that they will be compensated by a much larger business for the reduction of profits on a smaller turnover. On the first point an intelligent survey of the field will soon carry with it conviction. Individual enterprises in the new districts may have reached their greatest development or may do so in the near future, but enough attention has now been given to the copper resources of the Rocky mountains to warrant the assertion that the virgin ground already explored will make good any decline in other quarters. On the second point hesitation is better founded, and may only be dispelled by competition by new works.

No question has probably been as variously discussed during the constant decline of values as that relating to the capacity of the different mines to outlive low prices. It has been already pointed out that even poor mines will continue to struggle much longer than is generally believed. During the year 1884 there was probably not a copper enterprise in the United States which has not had every item of cost subjected to the closest scrutiny. So far as the Lake Superior mines are concerned it is a comparatively easy matter to arrive at the proportion of the yield in 1883 and 1884 which has resulted in a profit to the mines. Out of the total product in 1883, of 59,702,404 pounds, about 49,500,000 pounds, or 83 per cent., were produced at figures below the market rates, while in 1884 the figures may be placed at 69,250,000 and 54,000,000 pounds, respectively, assuming the average price to have been 11½ cents. It must not be forgotten that the average price realized is lower in reality than the average market rate in this country, because the returns obtained from that part of the yield which is marketed abroad are lower. So far as the other producing regions are concerned, their mines are, with but a few exceptions, in the hands of firms or close corporations, whose business affairs are not a matter open to public discussion. In some important instances, too, the base metal is a mere carrier of the precious metals, or the presence of the latter in the ore is an important factor, thus rendering the producers more or less independent of the market value of the copper. It may be stated, however, without disclosing private affairs, that out of the total product of Montana certainly a very large percentage yielded a profit, and that out of the whole make of Arizona not less than 90 per cent. was placed on the market, in 1884, at remunerative rates. It is not held, however, that these figures represent the maximum figure, because there are a number of other enterprises, great and small, concerning which no data have been available. Viewing it in a different light, it may be said that out of the total output of the United States in 1884 fully 70 per cent. can be put on the market at 11½ cents for Lake Superior copper, and at 10½ cents for other kinds. These prices are very low as an average of the price realized in 1884.

The decrease in dividends during the years 1883 and 1884 furnishes a striking illustration of the pressure of the decline. The profits paid to shareholders of public companies during these years were as follows:

Dividends of copper mining companies.

Name of mine.	1882.	1883.	1884.
Calumet and Hecla (Lake Superior)	$2,000,000	$2,000,000	$1,300,000
Quincy (Lake Superior)	440,000	380,000	280,000
Osceola (Lake Superior)	200,000	200,000	62,500
Atlantic (Lake Superior)	80,000	80,000	40,000
Central (Lake Superior)	60,000	60,000	40,000
Franklin (Lake Superior)	....	80,000	80,000
Copper Queen (Arizona)	325,000	500,000	200,000
San Francisco (California)	....	2,500	....
United Verde (Arizona)	....	37,500	60,000

In addition to these published dividends other profits have been distributed to shareholders in close corporations, among which the Montana Copper Company and the Parrot Silver and Copper Company, both of Butte, may be mentioned.

In some instances these dividends were only earned in part by copper mining operations, being in one case the return from sales of lands, and being in more than one concern partly made up by drawing upon reserve funds. On the other hand it is only fair to state that in many other cases profits earned were invested in extension of plant and equipment, in the accumulation of supplies and working capital, and in the payment of interest charges upon debt inherited from former mismanagement.

How much was irretrievably sunk in the opening of mines and the purchase of plant by concerns unable to meet the market, it is impossible to form any correct idea of. Much of the capital thus invested will become productive as soon as there is a recovery of values, as soon as better transportation facilities are afforded, or supplies, fuel, and labor decline as the consequence of a development of the regions in which they are located. There can be no doubt, however, that very large sums of money have been injudiciously expended and may be counted as a dead loss to the investors. In more than one case absurdly high amounts were paid for property, and serious blunders have been made in building unsuitable or inefficient reduction plant.

The years 1883 and 1884 have therefore been far from being prosperous years for the copper industry of the United States. They have, however, fully proved the vitality of the new districts of the West. They have shown how great are the resources of that part of our country, and have laid the foundation of an industry which is capable of considerable expansion still, and is sure to prove highly remunerative in the future. Individual enterprises may decline, and some of the districts now the scene of considerable activity may be robbed of their importance, but enough has been shown during the past few years of prospecting and development to warrant the statement that our copper resources are far greater in magnitude than even the most sanguine were led to believe two years ago. The opening of the western mines may be regarded as the direct result of the rapid extension of the railroads in the Rocky mountains, cheapening the cost of suitable fuel and the shipment of product. Thus far they have not had the leveling effect upon wages which follows an increase of population and a lower cost of living, and in this direction the future may bring relief to many struggling enterprises. In the southwestern tier of Territories the deposits, so far as they are known by development, carry oxidized ores, often of great richness and in large bodies. As yet they have not been opened to such a depth that unaltered ores have been reached, and the questions affecting their future, when that period does arrive, have not yet been brought up. As a general thing it may, however, be stated that from the character of the deposits and of their ore contents their life is not looked upon as being assured for long periods. But there is so much unprospected ground, so much partially opened, that no serious decline is feared. These Territories are not threatened with a repetition of the short-lived early copper excitement of California. Montana's future as a copper-producing section is assured for many years to come. The great mass of the ore is undoubtedly low in grade, comparatively speaking, but it has proved to be unusually abundant, and is handled with skill and enterprise. Besides these prominent regions, well-authenticated reports come from almost every quarter of the Rocky mountains of promising prospects, some of which will unquestionably develop into important producers. It may, therefore, be stated with confidence that taken as a whole the western States and Territories have proved their ability to become great factors of permanent importance in the copper industry of this country and of the world.

In the Lake Superior region the past two years have practically sounded the death knell of many of the smaller mines, and have borne heavily on the future of ventures into which heavy amounts of capital had gone only a few years since, encouraged chiefly by the prospects of remunerative employment through the introduction of modern methods of extraction and ore treatment. A good deal of progress has been made in that direction, and some relief was obtained by a lowering of the cost of supplies and of wages. But the decline was so heavy that the restriction of expenditures could not keep pace with it, and for some time to come new investments in the mines of the region will not be heavy. The larger, more prosperous concerns have been forced to an increased output, and all but a few of them are now able to continue work at least without loss, though not with the phenomenal profits of the past. There is still an enormous amount of unexplored ground which promises to afford the opportunities for a steadily growing industry.

It may be stated in a general way that the Lake Superior mines possess all the elements of stability, while on the whole those of the far West may be looked upon as subject to greater fluctuations individually and collectively, with the exception always of the Montana mines, where the main dependence is upon the cheap handling of large quantities of ores, which under local conditions must be pronounced low grade. It must be clearly understood in regard to the latter that their similarity with certain great mines of Chili makes it a matter of little doubt that greater depth will reveal changes to unaltered low-grade ores. The future can only teach whether the output can then be maintained. In the meanwhile there are very heavy known reserves, and no signs of changes in the character of the ores have appeared.

DOMESTIC PRODUCTION.

The growth in the production of copper in the United States, compiled up to 1884, inclusive, from the best data available, is shown in the following table. It proves in a striking manner how preponderating was, until the past few years, the influence of the Lake Superior district; and again of one great mine in it, the Calumet and Hecla, for more than a decade. In order to point out more clearly how preponderating has been the output of the Lake district from 1847 to 1880, a column has been added giving its percentage of the total product from year to year. It should be stated that the yield of copper from pyrites is not here included.

Production of copper in the United States from 1845 *to* 1884, *inclusive.*

Years.	Total production.	Lake Superior.	Calumet and Hecla.	Percentage of Lake Superior of total product.	Years.	Total production.	Lake Superior.	Calumet and Hecla.	Percentage of Lake Superior of total product.
	Long tons.	*Long tons.*	*Long tons.*			*Long tons.*	*Long tons.*	*Long tons.*	
1845 ...	100	12	....	12.0	1866 ..	8,900	6,138	....	68.8
1846 ...	150	26	....	17.0	1867 ..	10,000	7,824	603	78.2
1847 ...	300	213	....	71.0	1868 ..	11,600	9,346	2,276	80.6
1848 ...	500	461	....	92.5	1869 ..	12,500	11,386	5,497	95.1
1849 ...	700	672	....	96.0	1870 ..	12,600	10,992	6,277	87.2
1850 ...	650	572	....	88.0	1871 ..	13,000	11,942	7,242	91.9
1851 ...	900	779	....	86.6	1872 ..	12,500	10,961	7,215	95.7
1852 ...	1,100	792	....	72.0	1873 ..	15,500	13,433	8,414	87.3
1853 ...	2,000	1,297	....	64.9	1874 ..	17,500	15,327	8,984	87.6
1854 ...	2,250	1,819	....	71.1	1875 ..	18,000	16,089	9,586	89.4
1855 ...	3,000	2,593	....	86.4	1876 ..	19,000	17,085	9,683	88.9
1856 ...	4,000	3,666	....	91.6	1877 ..	21,000	17,422	10,075	82.9
1857 ...	4,800	4,255	....	88.7	1878 ..	21,500	17,719	11,272	82.4
1858 ...	5,500	4,088	....	74.3	1879 ..	23,000	19,129	11,728	83.2
1859 ...	6,300	3,985	....	63.3	1880 ..	27,000	22,204	14,140	82.2
1860 ...	7,200	5,388	....	74.8	1881 ..	32,000	24,363	14,000	76.1
1861 ...	7,500	6,713	....	89.1	1882 ..	40,467	25,439	14,309	62.1
1862 ...	9,000	6,065	....	67.4	1883 ..	51,574	26,653	14,788	50.1
1863 ...	8,500	5,797	....	67.0	1884 ..	63,555	30,916	17,812	48.4
1864 ...	8,000	5,576	....	69.7					
1865 ...	8,500	6,410	....	75.4	Total.	512,146	376,047	173,901	73.4

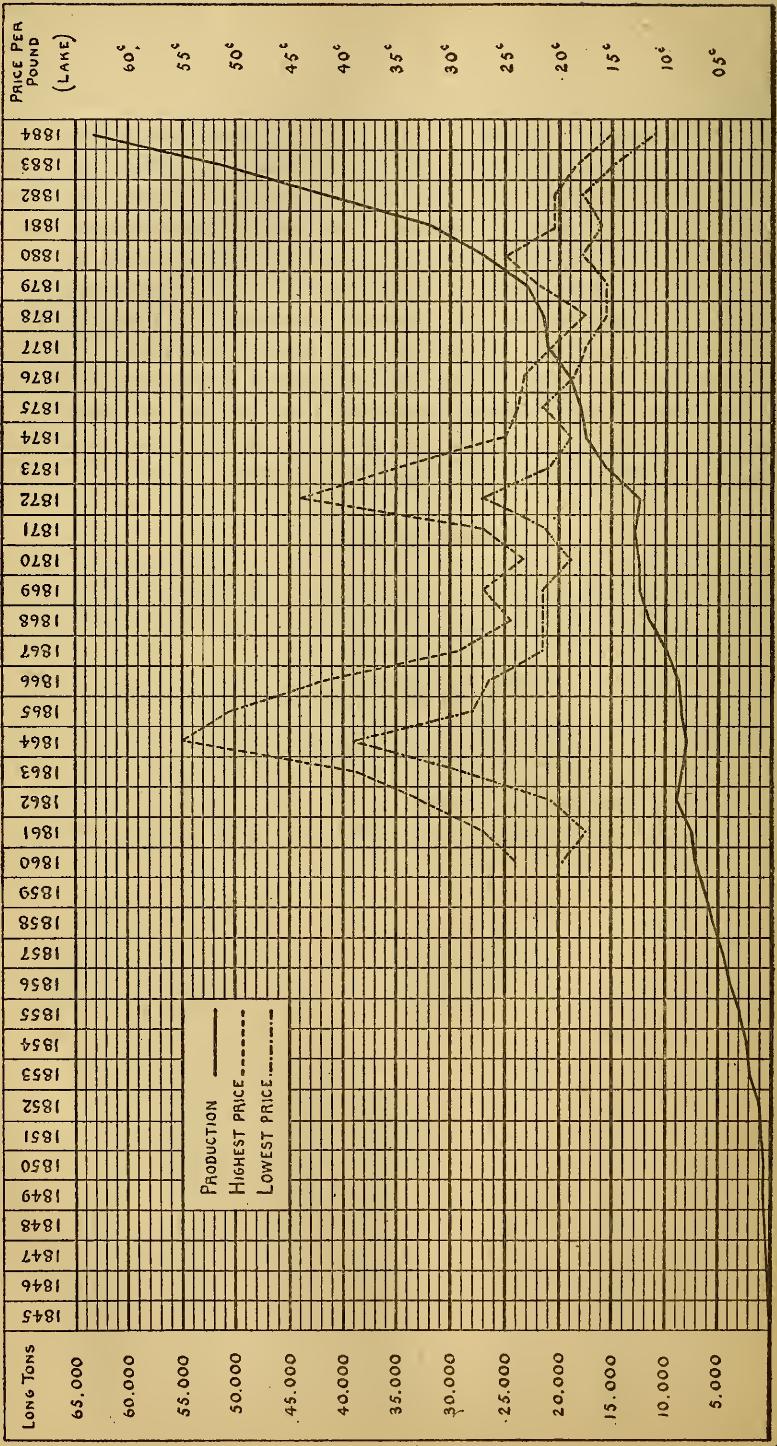

FIG. 3.—PRODUCTION OF COPPER IN THE UNITED STATES, 1845 TO 1884 INCLUSIVE, AND PRICE SINCE 1860.

As in the past, it has been a matter of little difficulty to collect nearly complete returns from the Lake Superior mines. For the year 1883 the official figures by the Hon. A. P. Swineford, commissioner of mineral statistics of Michigan, have been followed:

The production of Lake Superior copper mines in 1882, 1883, *and* 1884.

Mines.	1882.	1883.	1884.
	Pounds.	*Pounds.*	*Pounds.*
Calumet and Hecla	32, 053, 539	33, 125, 045	40, 473, 585
Quincy	5, 665, 796	6, 012, 239	5, 680, 087
Osceola	4, 176, 782	4, 256, 409	4, 247, 630
Franklin	3, 204, 120	3, 488, 708	3, 748, 652
Atlantic	2, 631, 708	2, 682, 197	3, 163, 585
Allouez	1, 683, 557	1, 751, 377	1, 932, 170
Pewabic	1, 482, 666	1, 171, 847	227, 834
Central	1, 353, 597	1, 268, 556	1, 435, 000
Grand Portage	757, 080	735, 598	255, 860
Conglomerate	734, 249	222, 117	1, 152, 224
Mass	666, 086	659, 474	481, 396
Copper Falls	587, 500	804, 000	934, 000
Phœnix	560, 985	512, 291	572, 427
Hancock	540, 575	484, 906	562, 636
Huron	364, 579	720, 213	1, 927, 660
Ridge	102, 936	60, 155	74, 030
Saint Clair	87, 126	125, 225	175, 619
Cliff	66, 053	10, 374	37, 924
Wolverine	65, 457	699, 622	751, 763
Nonesuch	46, 454	....	....
Isle Royal	29, 730	....	....
Minong	21, 380	3, 582	....
National	17, 560	26, 006	....
Minnesota	10, 672	6, 226	....
Belt mines	5, 720	16, 402	130, 851
Shelden-Columbian	3, 300	....	....
Aztec	3, 129	....	....
Adventure	429	....	....
Peninsula	....	829, 400	1, 223, 700
Tamarack	....	7, 435	....
Ogima	....	3, 000	....
Total	56, 982, 765	59, 702, 404	69, 188, 633

The figures for 1884 are official estimates. A few small mines have not reported, but their product is not likely to affect the general result to the extent of 60,000 pounds. Estimating their product at about that figure, we reach a total, in round numbers, of 69,250,000 pounds.

Total copper production in the United States in 1882, 1883, *and* 1884.

Source.	1882.	1883.	1884.
	Pounds.	*Pounds.*	*Pounds.*
Lake Superior	56, 982, 765	59, 702, 404	69, 250, 000
Arizona	17, 984, 415	23, 874, 963	26, 734, 345
Montana	9, 058, 284	24, 664, 346	40, 612, 783
New Mexico	869, 498	823, 511	59, 450
California	826, 695	1, 600, 862	876, 166
Colorado	1, 494, 000	1, 152, 652	2, 013, 125
Utah	605, 880	341, 885	265, 526
Wyoming	100, 000	962, 468	....
Nevada	350, 000	288, 077	100, 000
Idaho	....	....	46, 667
Missouri	294, 695	260, 306	230, 000
Maine and New Hampshire	290, 000	212, 124	249, 018
Vermont	1, 265, 000	400, 000	655, 405
Southern States	400, 000	395, 175	317, 711
Middle States	....	64, 400	2, 114
Desilverizers, etc	125, 000	782, 880	950, 870
Total domestic copper	90, 646, 232	115, 526, 053	142, 363, 180
From imported pyrites	1, 000, 000	1, 625, 742	2, 858, 754
Total, including copper from imported pyrites	91, 646, 232	117, 151, 795	145, 221, 934

The difficulties of arriving at an accurate estimate of the production in the western States and Territories have been largely increased by special circumstances. There has been a far greater alacrity in making full returns, but notably in the case of Montana producers they are not quite as definite as might be desired, though it must be conceded that often it is difficult for shippers of ore and matte to give a close estimate of the copper contents of the ore or furnace products sold by them. A valuable check upon the direct returns has been obtained through the courtesy of all the refineries, with the exception of one unimportant works.

Since a very large proportion of the total product was marketed abroad in a crude or partly-worked shape, it is practically impossible to make any trustworthy estimate of its value, especially as the payments made for argentiferous material abroad do not specify how much is returned for the one and for the other metal.

It should be noted, in connection with the figures given in this table of production, that a large part of the California, Nevada, and Colorado product, and the greater part of the quantity returned by desilverizers is used for the manufacture of bluestone.

It may be of interest to state that out of the whole domestic product of 1883 of 115,526,053 pounds of copper, no less than 92,500,000 pounds were converted into ingot copper in this country; and that in 1884 the quantity was 108,250,000 pounds out of a total product of 142,363,180 pounds, the decline in the percentage of the total treated in home works being due to larger shipments of ore and furnace material to foreign countries.

Refineries.—The business of copper refining has been practically concentrated in the hands of three concerns, for metal produced in districts outside of Lake Superior. These works are: Pope, Cole & Co., of Baltimore, Maryland; the Orford Sulphur and Copper Company, New York; and the Ansonia Brass and Copper Company, Ansonia, Connecticut. Some refining is also done by the New Jersey Extraction Company, Elizabethport, New Jersey; the Revere Copper Company, Boston, Massachusetts; Taunton Copper Manufacturing Company, Taunton, Massachusetts; and the Harris Copper Company, Sainte Genevieve, Missouri. Messrs. Balbach & Son, of Newark, New Jersey, have during the latter part of 1884 begun to refine argentiferous Montana mattes by the electrolytic process which they have for some time had in use in parting bullion. They convert the matte into blister copper, or work the blister made by the Manhès process. The copper is sold largely for export in the form in which it is stripped from the plates, cut into convenient shapes to suit the views of customers. Early in 1885 the Saint Louis Smelting and Refining Company at Cheltenham, Missouri, has also begun to deposit copper electrolytically.

The Orford Copper and Sulphur Company is regularly working argentiferous material, and Pope, Cole & Co., of Baltimore, also extract silver.

THE COPPER DISTRICTS OF THE UNITED STATES.

Lake Superior.—During the years 1883 and 1884 there have been comparatively few new developments in the Lake mines. New companies, reworking old mines like the Peninsula, the Belt, and others, have either entered the lists of producers or have made preparations for output. A good many of them have been seriously crippled by the unprecedented decline of the metal, which otherwise might have started in their career with fair promise of success. A number of the small mines have already or will in the near future cease operations, and the tendency appears necessarily to be toward the restriction of the make to a comparatively small number of large mines. Copper mining on the lake, reviewing the history of all the old and new mines, has been far from being as remunerative as is generally believed. It is true that the acquirement of the knowledge of the standard methods now in general use has borne a goodly share of the losses, and that many mines abandoned nearly a generation since as incapable of yielding profits would be to-day properties paying regular dividends. But the experience of the past few years is well calculated to discourage, for a time at least, the investment of the very heavy amounts of capital needed, and the Lake region must look to its growth as the leading copper-producing section in the country rather to an extension of the operations of the mines now working at a profit or at least at only a slight loss. The following table, giving the cost of production of the principal mines in the years 1875, 1881, 1882, and 1883, will furnish some means of gauging the capacity to meet the market and of tracing the result of the efforts to reduce the cost. No figures are available upon which it would be possible to base any authoritative estimate concerning the cost price per pound of the Calumet and Hecla mine; but it may be stated that it is certainly lower, excluding construction account, than that of any mine in the list.

Cost of production of Lake copper, per pound.

Mines.	Production (in pounds).		Cost of production (in cents per pound).					Yield (per cent.).				
	1883.	1882.	1884.	1883.	1882.	1881.	1875.	1884.	1883.	1882.	1881.	1875.
Quincy	6,012,239	5,665,796	8.63	9.00	9.55	10.03	15.79	2.70	2.86	3.21	2.62	......
Osceola	4,256,409	4,176,782	11.24	12.21	12.97	....	....	1.17	1.21	......	1.29	......
Atlantic	2,682,197	2,631,708	10.88	12.56	13.80	13.68	22.12	.75	.68	.69	.72	.78
Central	1,268,556	1,353,597	......	15.4	14.76	14.24	15.81	......	1.90	2.20	1.58	2.65
Allouez	1,751,377	1,683,557	13.46	15.98	17.38	19.32	....	.85	.86	.85	.95	......
Franklin	3,489,308	3,264,120	11.62	12.96	13.00	....	....	1.45	1.38	1.10	......	......
Pewabic	1,171,847	1,482,666	....	21.47	17.00	16.36	....	......	1.01	1.00	1.38	......

It will be observed, therefore, that where the conditions affecting the mines remained fairly uniform, there has been a marked lowering of the cost of production at the Lake Superior mines during the year 1884.

This is the result not alone of a scaling down in wages of about 10 per cent., but also by the exercise of the greatest economy in all departments, and of lower prices of supplies, particularly the explosives used. Special efforts have been made in a great many mines to distribute fixed charges over a larger product, by increasing power-drilling and crushing plant. The most extensive work in this direction has been done by the Calumet and Hecla Mining Company, which is now on the eve of the completion of its enormous hoisting and crushing plant. At the mine the entire system of machinery has been so arranged that every motor is practically duplicated to prevent any stoppages. The old mine is opened out, with ground blocked out for years to come, and the vein has been opened to considerable depth at the south end, where practically a new mine has been developed. At the stamp mill Leavitt heads, which admit of a large saving of fuel and an increased capacity, have replaced the Ball stamps, and the mill will during the current year be in a position to crush daily, with ten Leavitt stamps and two in reserve, fully 2,250 tons of rock, equivalent to an annual output of 30,000 tons of ingot. Had it not been for the breaking out of the fire in October, which caused a falling off of the product of about 700 tons, the output would have been 41,300,000 pounds of ingot. At the present rate of nearly 100 tons of mineral per day, next year's yield would be 23,000 tons of ingot, which will, however, be increased as the new equipment becomes available for steady work. The Osceola company has has added a fourth stamp; the Allouez, one Ball head; the Atlantic a fifth Ball head, capable of crushing 180 tons per day, and the Huron a second head. The Peninsula company, one of the mines which has entered the ranks of the larger producers, has two Ball stamps, the Conglomerate has three Ball heads, while the Tamarack, a new mine opening the Calumet and Hecla conglomerate at greater depth, has only recently selected a site for its mill. As yet it is impossible to judge whether all of this new equipment will be made to do duty, but the combined additional product of the large companies will probably outstrip the total falling off due to the closing of the weaker mines.

How enormous is the investment of capital needed for the equipment of a Lake Superior copper mine, crushing rock carrying less than 1 per cent. of the metal, is strikingly illustrated by the report for the year 1883, of the Conglomerate Mining Company. In the three years 1881, 1882, and 1883 the company spent $1,288,753.73, or deducting sundry credits, copper sold and on hand, $961,737.06. All but $381,446.02 of this amount is for machinery, plant, railroad, and surface equipment, including $43,072.51 for an air compressor, $145,685.17 for a railroad 7.6 miles long to the mill, $182,047.32 for a new mill, and $44,411.41 for a hoisting engine. The crushing capacity of the 3-stamp mill may be estimated at about 180,000 tons per annum, equivalent, with a fair grade of rock, to a yield of about 1,800,000 pounds of ingot. Mr. Henry C. Davis, president of the Conglomerate Mining Company, has submitted a highly interesting statement giving in detail the cost in 1884, per ton of rock stamped. The figures which are given below would have been materially lower if the cost had been based on the quantity of rock broken.

Cost per ton of rock stamped, Conglomerate mine, 1884.

Mine cost	$0.7299	
Compressor cost	0.0423	
Pumping	0.0101	
Hoisting	0.0731	
Total mining cost, delivered on surface		$0.8554
Handling in shaft houses	0.0283	
Transportation to rock house	0.0217	
Breaking in rock house	0.1084	
Transportation to stamp mill and maintenance of 7 miles of railroad	0.0626	
Total handling between mine and stamp mill		0.2210
Stamping and dressing		0.4170
General surface expenses	0.0366	
Office and general expenses	0.0525	
Superintendence and general expenses		0.0891
Total cost		1.5825

These figures represent the average for the whole year, stamping 120,844 tons, from which 1,682,080 pounds of mineral or 1,152,224 pounds of ingot were produced. The cost has, however, been considerably reduced during the year. It was $2.139 per ton of rock stamped in January, $1.918 in March, $1.477 in June, $1.274 in September, and $1.258 in October. These figures are of great interest, as showing what a modern plant can do working on conglomerate rock, reaching figures that compare favorably with mines working on amygdaloid; especially since only two of the three stamps were crushing, on an average. The grade of the rock crushed by the Conglomerate appears to have been very low, 0.476 per cent. of ingot, and the mill is now shut down, only a small force being kept sinking to test the ground in depth.

The result of an increase in capacity is clearly illustrated by the figures published in the report for 1884 of the Allouez Mining Company. During the first nine months of the year, while working two heads of stamps, the expenses per pound of refined copper were 15.54 cents. During the last three months with three heads of stamps they declined to 12.43 cents.

The difference between the cost of all-rail transportation of Lake copper, as compared to the rates of water, while lake navigation is open, is not as great now as it was at one time. It is now $6 per ton during the summer and $11.50 during the winter, so that in the case of scarcity in winter the supplies at the refineries could be drawn upon as soon as an advance of one-quarter of 1 cent had taken place. The margin for a speculative profit by concentrating Lake copper in a few hands while lake navigation is closed is not therefore as wide as it was in former times, when advantage was repeatedly taken of it. The charge for smelting mineral is $13 per ton, and that for working slags about $9 per ton—charges against which there has been some agitation.

Taking into account the fact that many of the means of economy practiced have only told during a part of the year 1884, and that more of them will come into play only in 1885, it may be stated that the leading Lake mines have proved their ability to meet the markets of the world and of their competitors in this country. Unless policy dictates a curtailment, of which there is little prospect, the quantity produced will rather show an increase than a decline.

Arizona.(*a*)—There have been many changes in the list, notably of the smaller copper mines of Arizona. In the Bisbee district the Copper Queen has remained the only producer, the Copper Prince shipping only high grade ore, while the Holbrook and Atlanta mines are being opened up with good prospects. In the Globe district, the Tacoma, Long Island, and others closed down in 1883, and the Old Dominion company was the only one which, favored by the discovery of a large body of high grade ore, was able to stand the strain of low prices of copper and high cost of fuel and transportation. Clifton, where the Detroit and Arizona companies are working, has more than held its own and has the advantage over the other districts of having railroad connections. The Detroit company, managed with ability, has remodeled its smelting works, putting them up at the mines to avoid hauling the ore 7 miles, and has provided a pump and pipe line to force water from the San Francisco river to the smelter, a distance of 31,000 feet and an elevation of 1,500 feet. All the mines are connected with the smelting works by a 20-inch tramway, the ore yielding in the furnaces, inclusive of the low grade iron for flux, 12.5 per cent. The Arizona Copper Company, limited, has also built a new extensive plant, and completed the railroad to Lordsburg, but the mines have not been able to supply the smelter to its excessive capacity with sufficiently high grade ore, and the company, a Scotch concern, has labored constantly with financial difficulties.

Mr. Carl Henrich, M. E., who has studied the Clifton district, protests against the application to this district of the verdict given generally in regard to deposits of oxidized ores in limestone, that they are pockety and liable to exhaustion at any time. He states that the copper deposits of the Clifton district occur either directly at the contact of porphyry and limestone, or in very close proximity to the contact. The ores are classified as ferruginous, calcareous, and manganiferous and siliceous copper ores. Thus far the bulk of the ore smelted has belonged to the first class. The deposits have only been worked in a few instances in a systematic manner, and have been found persistent, and the large number of good prospects encourages the belief that so far as the ore supply is concerned the district will rank as a leading

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[a] See also the paper by Mr. James Douglas, jr., on "The Cupola Smelting of Copper in Arizona," in this volume.

producer for many years to come. The mines are very dry, and with Mexican labor receiving $2 per day and white miners $3, the cost of mining, deadwork, and hauling to smelter when reasonably near the mines, is estimated at $4.50 per ton. Coke costs $40 per ton, including $12.50 for waste in transportation from San Francisco to smelter. With a modern 14-tuyere furnace, such as that designed and built by Mr. Henrich for the Detroit company, 7½ tons of ore are smelted per ton of coke; putting through 80 tons per day, the total cost of smelting is $7.20. On the basis of these figures, Mr. Henrich estimates the cost of laying down copper in New York, refined, at 10.15 cents for a 9 per cent. ore, 9.44 cents for a 10 per cent. ore, 7.84 cents for a 12 per cent. ore, and 7.14 cents for a 15 per cent. ore. With a smelter like those generally used in Arizona, having a capacity of 35 tons per day, the cost, including a necessarily higher outlay per ton for mining due to smaller production, would be per pound of refined copper laid down in New York, 11.5 cents for 9 per cent. ore, 10.64 cents for 10 per cent. ore, 9.25 cents for 12 per cent. ore, and 7.94 cents for 15 per cent. ore, the allowance for freight and refining being in all cases 2½ cents per pound, which appears ample. Although these figures have not been reached in practice, they indicate that, with careful management, the Clifton mines are in a position to compete at present and even at lower prices.

Turning to the Bisbee district, we have as the leading representative the Copper Queen Mining Company, which has remained the most profitable copper enterprise in the West during the years 1883 and 1884. According to the annual report of the company for the fiscal year ending April 1, 1884, the mine produced during that period 33,961 tons of ore, 33,941 tons of ore being smelted with a consumption of 6,383 tons of coke and 3,617 cords of wood for steam raising. The ore averaged 11.26 per cent. of black copper, the total product of black copper being 7,647,488 pounds, averaging 96.3 per cent. fine. The actual sales of black copper and of ingot during the fiscal year footed up to $1,297,565.63. The net value of the bullion produced at New York was $1,033,045.62, from which are deducted $690,099.55 for operating expenses, freights, refining, and administration, leaving a net profit of $342,946.07. As the dividends aggregated $450,000, the surplus of $267,028.51 on the 1st of April, 1883, was reduced to $159,974.58 on April 1, 1884. On the basis of these figures the cost per pound of ingot copper laid down in New York is 9.40 cents. Since then wages have been reduced, and the cost price has probably declined further.

The Atlanta, a mine adjoining the Copper Queen, has during the past few years opened very large bodies of ore and promises to become an important factor. The Copper Prince, another mine near the Copper Queen, has shipped considerable very high grade ore during 1884, and has accumulated reserves of lower grade ores during development work.

In the Globe district the only company now at work is the Old Dominion Copper Mining Company, which opened out a large body of ore in the Old Globe mine acquired by it, and produced a heavy amount of copper in 1884. During that years 2,336 tons of ore were smelted, which yielded 15.83 per cent. of copper, the ore averaging during that year 17.33 per cent. This high grade has more than compensated for the heavy expense of carrying the coke and supplies to Globe and taking back the metal, and has enabled the company to produce at a profit, even at the lowest prices touched. The other concerns in the district, the Long Island, Tacoma, and others, stopped work early in the year.

The Peabody, acquired by the Cochise Copper Company, in May, 1883, continued working until March, 1884, when the works were shut down on account of the low price of copper. The works produced considerable black copper and some matte.

The Copper Mountain mines consolidated in October, 1884, with the Hartford Copper Company, and the new corporation resumed work on its mines in November. A number of other enterprises were checked in their early stages by the fall in the price of copper, the furnaces either being only partially erected or run only for periods varying from a few days to a month. In some instances the plants have been dismantled and sold. On the other hand new producers have entered the list during the past two years, the most prominent of them being the United Verde, of Jerome, Yavapai county, 30 miles northeast of Prescott, which in 1883 and 1884 paid out $97,500 in dividends. It is the only producer of argentiferous copper in Arizona, and is reported as having large reserves in sight. A second furnace has been built, but smelting operations have been suspended on account of the low price of copper and in anticipation of railroad connections, which it is hoped will be available in July, 1885. Very large quantities of silver are at times contained in the black copper and the matte. Another new enterprise is the Casa Grande Copper Company, which is situated in the Casa Grande district, 40 miles southwest of the railroad. The mine has been opened to a depth of 200 feet, the ore being oxides and carbonates, averaging 12 per cent. Two furnaces have been erected, only one of which has been running, owing to a lack of water, until November. Lately the production has been suspended through lack of ore.

Montana.[a]—The reticence of some of the producers, among them the largest in the Butte district, has made the collection of statistics for 1884 a particularly difficult matter. For 1883, however, the data are nearly complete, since every mine sent either full data or estimates which allowed of a close approximation. An effort has been made to arrive at a satisfactory estimate, in spite of the refusal to give information. From the returns of the railroads giving shipments of ore and matte it has been possible to closely approximate the quantity sent to

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[a] See also the paper by Dr. E. D. Peters, jr., on "The Mines and Reduction Works of Butte City, Montana," in this volume.

market by the Anaconda mine, the figures of other important shippers being known. A check upon them, of some value, was furnished by the statement of the exports of this country, although it does not specify the quantities of matte sent abroad. Then, on the other hand, the returns of American refiners of copper giving the quantity of fine copper produced from Montana material was of great service. The quantities thus arrived at are lower than those indicated by the estimates of receipts of fine copper from American ores in England. It is believed, however, that the latter include Mexican ores, chiefly from Lower California, shipped from San Francisco. A matter which makes all such estimates precarious is the fact that the grade of the shipping ore varies within wide limits. It must be noted, however, that one shipper reports that 11,000 tons sent abroad through him averaged 25 per cent. of copper, which is considerably lower than the general average assumed. Under the circumstances the production reported is as close an estimate as a cautious and thorough examination of the facts available could make it. It is unfortunate that important interests should refuse data especially at a time when an excitement produced by exaggerated reports has done much to unsettle values. Uncertainty in such contingencies is worse than the truth, even if the latter presents an unexpectedly unfavorable state of affairs.

As for the immediate future of the copper production of Montana one important fact must not be left out of consideration. The heavy shipments of rich ores may be expected to decline very rapidly and its output will henceforth depend more upon the quantities of matte produced at local smelting works by the treatment of low-grade ores previously concentrated. It becomes therefore more a matter of the capacity of the works. Most of them have been enlarged during 1884, and the largest has not yet, at the close of the year, worked long enough to allow of anything but approximations of its possible maximum output. This undoubtedly is very heavy, but it remains to be seen whether the estimates made can be accomplished in actual work. If the plants now in operation can be run continuously with ores of the same grade as that hitherto treated, the record of 1884 will be outstripped.

An opinion which has been gaining ground is that all of the Butte ores carry paying quantities of silver. If correct, this would put the district into a much more favorable position than it really is. Such is not the case, however. On the contrary, indications point in the other direction; that, in reality, a smaller proportion of the ore is sufficiently silver-bearing to carry the matte produced within the limits of profitable extraction. Some data as to the silver contents of mattes has been furnished, but they are not complete enough to allow of the presentation of any specific figures. The question is one which influences the prices realized very considerably, and therefore affects the capacity of Butte copper mines to resist low prices.

The other factors affecting the cost of production are cost of labor, fuel, and transportation. On the first point the following figures of wages may be submitted: Miners, $3.50 per day; laborers, $3 per day; furnacemen, $4; foremen, $5 to $5.50; carpenters, $5 to $6; and masons, $6 to $8. Several attempts were made late in 1884 and during January, 1885, to force a lowering of wages, but unsuccessfully. Fuel was lowered during 1884, and coal is now purchased for $8 to $9 and coke for $16. Freights to Missouri points are about $20; to the Atlantic or Pacific, $23; and to Liverpool, $25 per ton, since reduced to $18. During 1884 considerable ore, in all about 4,000 tons, was sent via San Francisco and Cape Horn to Europe. At current figures for labor, fuel, and freights, the profit in concentrating and smelting copper ores carrying from 12 to 14 per cent., and little silver, is very small indeed; and it is reported that, in some cases, there is an actual loss. Returns on the basis of 9 shillings per unit, in England, leave practically nothing for the miner in shipping ore running 25 per cent. of copper.

Technically, the Butte copper industry made considerable progress in 1884. A matter which has attracted considerable attention has been the bessemerizing of copper matte at the Parrot works. It is reported that the concentration of the matte has been successful, that the elimination of the arsenic is almost perfect, but that, on the other hand, the losses of silver are heavy.

In the beginning of December the Anaconda and Saint Lawrence miners were sending to the concentrating works about 300 tons of ore carrying about 14 per cent. of copper, and were supplying the furnaces about 100 tons per day of smelting ore averaging about 24 per cent. of copper. The concentrates yielded, by working from 200 to 500 tons of 14 per cent. ore, 30 per cent of copper, which goes to the roasting furnaces. The latter were putting through 10 tons per day, an excessive quantity, since the sulphur contents remained as high as 12 to 14 per cent.

The matting furnaces are rated at a capacity of 5 tons of matte per day, with a fuel consumption of 5 tons of coal per day. This would give the plant a capacity of 130 tons of matte per day, carrying about 60 per cent. of copper and 18 ounces of silver; but the furnaces were not kept running continuously, and during November and December they were turning out from 70 to 80 tons of matte per day.

The Anaconda works consist of a concentrator having 12 sets of rolls and 72 jigs, the capacity of which was rated at 500 tons, but which will not, when it gets into full running order, exceed 400 tons per day of concentrating ore. The smelting plant includes 26 calciners and 26 matting furnaces, to which are being added 12 new hand roasting furnaces. There has been in contemplation the erection of a new concentrating works equal in capacity to the one now running, but the last proposition is to put in a large compound engine to assist the present water-power, and in this manner make the most of the plant. A new addition to the smelting plant of 6 calciners is building. It is estimated that when these contemplated extensions are completed in the course of the year, the plant will have a capacity of 160 tons of matte per day. How far these expectations will be realized remains to be seen. It is urged that the railroad facilities of the works are not equal to hauling the enormous amount of ore which such a product would represent. On the other hand the plant has thus far been at work only three months in 1884, and it is impossible at this time to judge from its record what its achievements will be when the entire working is systematized. It is estimated by persons well qualified to judge that even when strained to full capacity the Anaconda will not in 1885 turn out more than 28,000 to 30,000 tons of matte, equivalent to about 25,000,000 to 36,000,000 pounds of fine copper.

It is just to state in this connection that the above data are not official. They have been gathered from various sources and are presented in the absence of official statements as the best information available. Since the Anaconda works were built they have been very much improved and are now pronounced by leading metallurgists to be fully up to the best practice. The mine has become so great a factor in the position of the copper supply that as close an approximation as possible to an estimate of its capacity is so important that such details as are available should be presented. The mine itself is generally pronounced an exceptional one, and it is believed that with the best machinery and plant it is good for a much larger yield than 600 tons daily for a number of years. The investment in development and equipment has been very large, and so far as the latter is concerned has not at first come up to expectations. Good authorities place the limit of cost, at the prices of labor and fuel at the close of 1884, at about 7¾ to 8 cents, below which only reductions in the items mentioned can force it.

The Montana Copper Company has made large developments in the East and West Colusa and in the Original Parrot mines. The plant has been enlarged during 1884, and now consists of two concentrating mills, each with a capacity of 75 tons of ore per day, one being used for the Parrot ores and the other for the argentiferous Colusa ores. The smelting works have twelve reverberatory calcining furnaces, six reverberatory matting furnaces, each capable of turning out 2 tons of fine copper daily, and one blast furnace for ferruginous ores, which produces 4 tons of fine copper daily. The policy followed during the year 1884 has been to extract those ores carrying larger quantities of silver, leaving those lower in silver though high in copper untouched, with a view to overcoming the low price of copper with the aid of the silver. In the future more copper ore lower in silver will be extracted, and the output of the works will be increased accordingly. In 1884 the matte averaged about 44 ounces of silver per ton of fine copper.

The Parrot Silver and Copper Company has two concentrating plants, one of 100 tons and the other of 250 tons daily capacity. It has an older plant of six calciners, capable of roasting daily 8 tons per furnace, and six new calciners, each 64 feet long and 13 feet wide, which work 11 tons per day each, with a consumption of wood of 2 cords per twenty-four hours. It has an older matting plant of six reverberatory furnaces with a daily capacity of treating 16 tons of ore per day, and a new plant, consisting of an 80-ton blast furnace provided with a large well from which the molten matte is tapped directly into a Manhès converter, which has been in successful operation during the last months of the year making blister copper free from arsenic from a rich matte, at the expense, however, of heavy losses of silver. The ore has not been running up to average, owing to the fact that a different system of stoping has been adopted. The matte carries on an average 30 ounces of silver per ton.

The Ramsdell-Parrot mine has shipped considerable ore to local smelters, which it is reported averaged about 20 per cent. of copper and 16 ounces of silver. It has recently improved its hoisting facilities.

The Bell company has a plant capable of treating 20 tons of 16 per cent. ore daily, making 55 per cent. matte, equivalent to 1,000 tons of copper per annum.

The Clark's Colusa has recently started a small concentrating plant and has a blast furnace on the ground. No data as to its capacity are at hand, and information concerning its output has been declined.

The works of the Colorado and Montana company treat ores particularly rich in silver, making a high-grade matte which is shipped to the Argo works of the Boston and Colorado smelting company. The quantity of copper made is comparatively small, and goes into other channels than the bulk of the Montana product.

New Mexico.—The low prices of copper have caused the cessation of almost all work. The most important mine is the Santa Rita, which has produced considerable quantities of very pure native copper in the past, and is fully equipped to begin work as soon as values recover. Other properties, notably the San Pedro, have been tied up by litigation.

California.—The principal producer in this State is the San Francisco Copper Mining Company, whose mines are at Spenceville, Nevada county, for details concerning the working of which I am indebted to Mr. John E. Ellis. The ore, of which about 75 per cent. has been extracted from an open cut and the remainder from the 150-foot level immediately below it, is a cupriferous pyrites, containing on an average 3½ per cent. of copper, 46.5 per cent. of sulphur, and 42.8 per cent. of iron, the balance being silica and traces of zinc and gold. In 1884 the quantity of ore hoisted was smaller than usual, being about 11,481 tons, since a considerable amount on fire in piles was carried over at the beginning of the year, and a great deal of dead work was done in opening the lower level, which is now in shape to produce regularly. From July to October, both inclusive, the precipitating works were rebuilt. After roasting in open heaps, the ore is leached in 40 wooden tanks 8 by 8 by 4 feet, the water being heated by steam. The resulting solution is run into large settling vats, where the percolations of the dump pile also accumulate, and from whence it is pumped into four revolving cylinders, 16 feet by 6 feet in diameter, which are charged with scrap iron for precipitation. Mr. Ellis states that mining in the open quarry, including hand breaking of ore and conveying to open heaps, costs on an average 35 cents per ton, and underground mining 90 cents to $1 per ton. The labor employed consists of four engineers, at $3 per day; two cylinder men, at $2.50; one blacksmith, at $3.50; one helper, at $2; one carpenter, at $3.50; six miners, at $3 per day; one man at leaching tanks, at $2.50; a foreman for the Chinese labor at the open heaps, at $3; one laborer for sacking precipitate, at $2; one teamster at $2, and thirty-five Chinese laborers, at $1.20 per day. The monthly fuel consumption averages 150 cords of wood, costing $4 per cord. Running altogether eight months in 1884, the works turned out 652,110 pounds of precipitate, averaging 81.6 per cent. of copper, equal to 532,121 tons fine. The bulk of it, about 35 tons per month, is disposed of on the Pacific coast for conversion into bluestone for the silver mills, the balance being shipped to eastern refining works.

A small quantity of cement copper has also been made at the Campo Seco, Quail Hill, and Napoleon mines, and at the Stella mine, Silver creek, Alpine county, which belongs to the Isabelle Gold and Silver Mining Company, limited, of London, England, and which produces at the same time some silver and gold.

Colorado.—The bulk of the copper produced in Colorado is obtained as a by-product in smelting, notably the argentiferous and auriferous ores of Gilpin and Clear Creek counties and the San Juan region, the copper acting as a carrier of the precious metals. The bulk of the ore is treated at the works of the Boston and Colorado Smelting Company. At the same time ores from other States and Territories are treated. Care has been taken to credit the quantities thus apparently originating in Colorado to its true source. A good deal of the product is exported, and the bulk of the balance is sold to manufacturers of bluestone, so that the amount of ingot copper refined at American works and destined for the American market is comparatively small. As the copper still contains considerable quantities of silver and gold, and is, besides, contaminated with tellurium, arsenic, antimony, and bismuth, it is not likely to be diverted from its present channels, unless the metallurgical methods undergo some change.

Considerable ore has been taken out of the Sedalia mine, at Salida, in the course of development work, which it is reported carries about 13 per cent. of copper. A small quantity was smelted during the year at Cañon City, where the Rocky Mountain Mine Developing Company has made a short campaign.

Utah.—The principal mine (the Crismon Mammoth) has been closed by litigation, and now only small quantities of ore are shipped to Colorado. A small smelter has been erected at Saint George during the year 1884.

Wyoming.—The copper resources of Wyoming have been claimed to be very extensive, a very large area having been prospected with encouraging results. The leading producer has been the Wyoming Copper Company, which has smelted in a 40-ton water jacket about 4,200 tons of carbonates and oxide from the Sunrise mines. This ore, which has averaged about 15 per cent., has iron oxide as the chief gangue, so that it is self-fluxing. The copper, which at one time reached the New York market in considerable quantity, was pronounced to be of good grade. Smelting was stopped after four months' run on account of the drop in the price of copper, the absence of railroad facilities making it impossible to meet the market. Being a hundred miles from the railroad, the coke cost, laid down at furnace, about $37 per ton, and the expense of hauling product was correspondingly large. Even with so heavy an expenditure for fuel the total cost per pound of copper at the smelter is put at 8½ cents, equivalent to 11½ cents marketed as ingot. The Sioux City and Pacific Railroad is now building toward the region in which the copper district is located, and, with proper facilities, a lower grade of ore can be worked at a lower cost. The district is, therefore, one that holds out a promise for the future.

Nevada.—The production has been limited, and the shipments of ore from Battle Mountain to England have ceased early in 1884.

Idaho.—Aside from small quantities of copper contained in gold and silver ores treated at such works as the Boston and Colorado Smelting Company, at Argo, Idaho has thus far produced no copper. Toward the close of November a smelting furnace was started in connection with copper mines at Houston, Big Lost river.

Missouri.—At the Genevieve copper mines continued work has been done during the past two years. On January 1, 1884, the Harris Copper Company leased the works to Messrs. Potter & Nicholson, who have worked only ore coming from the Cornwall mines, no refining of bars having been done by them. Work has stopped, and the establishment is for sale.

Texas.—Some attention has been given during 1883 and 1884 to the copper deposits of Texas. Mr. W. H. Streeruwitz, M. E., of Houston, states that those of Llano county are best known and best defined by outcrops. The copper minerals are found there as impregnations in granite and as veins with quartz gangue in granite, and are generally carbonates, the result of surface decomposition, and at greater depth are sulphurets and gray copper generally carrying gold and silver. Contact deposits between crystalline slates and granite are also known. The copper outcrops are more clearly defined north of the Llano river on the headwaters of Pecan, Babyhead, Little Llano, and San Fernando creeks. There are also copper outcrops in the northwestern corner of Llano county, running into Mason county, though they appear to carry only smaller quantities of the precious metals. Some of the Llano county veins may be traced over to San Saba county, and traces of old Spanish diggings show that at least attempts at working were made in spite of hostile Indians. Mr. Streeruwitz judges from samples said to have come from that quarter that pyritic ores prevail. He expresses the opinion that copper may be found in parts of the whole granite and crystalline slate belt which extends through parts of the counties of Burnet, Blanco, San Saba, Mason, Gillespie, and Menard.

A second group of copper deposits has been discovered nearly due north of the former, in the district embraced by Stonewall, Haskell, Baylor, Archer, and Wichita counties, south of the Indian Territory. Mr. E. T. Dumble, chemist and geologist, of Houston, pronounces it Permian. Mr. Streeruwitz states that the ore, carbonate, and pseudomorphous copper glance is found loosely distributed in a bluish gray clay. He adds that the ores seem to be washed down from the Wichita range. Large masses, weighing as much as 2 tons, have been found, but no vein has as yet been exposed.

The third field is in southwestern Texas, on the eastern slope of the Chinate mountains, near Fort Davis, and in the ranges between the latter point and New Mexico.

Very little systematic and well directed prospecting has as yet been done in Texas, and all but the few operations in charge of competent persons have failed disastrously. There are now, however, under way two or three well conducted enterprises, so that it is possible that at no distant time Texas may begin to figure as one of the copper-producing States. The most prominent is the Great Belt Copper Company, a New York organization, of which General G. B. McClellan is president. A force of thirty men is now engaged in doing preliminary work, and smelting furnaces have been ordered.

Dakota.—Thus far no copper has been produced in Dakota. The Gray Eagle Copper Mining and Smelting Company, however, is at work completing its smelter, which it is expected will blow in in May.

Vermont.—The Ely mines, at one time heavy and steady producers, have turned out a little copper in 1883, but since the middle of that year have been closed down by litigation. The Elizabeth mines of South Strafford have been smelting, however, until recently, when all but mining and roasting was suspended. Only a part of the product reached the market.

IMPORTS.

The imports of fine copper contained in ores, and regulus and black copper, and of ingot copper, old copper, plates not rolled, rolled plates, sheathing metal, and manufactures not otherwise specified, and of brass, are given in the following tables:

Fine copper contained in ores, and regulus and black copper imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Fine copper contained in ores.		Regulus and black copper. (*a*)		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1867	....	$936, 271	....	....	$936, 271
1868	3, 496, 994	197, 203	....	....	197, 203
1869	24, 960, 604	448, 487	....	....	448, 487
1870	1, 936, 875	134, 736	....	....	134, 736
1871	411, 315	42, 453	499	$60	42, 513
1872	584, 878	69, 017	4, 247	1, 083	70, 100
1873	702, 086	80, 132	1, 444, 239	279, 631	359, 763
1874	606, 266	70, 633	28, 880	5, 397	76, 030
1875	1, 337, 104	161, 903	12, 518	2, 076	163, 979
1876	538, 972	68, 922	8, 584	1, 613	70, 535
1877	76, 637	9, 756	1, 874	260	10, 016
1878	87, 039	11, 785	....	....	11, 785
1879	51, 959	6, 199	....	....	6, 199
1880	1, 165, 283	173, 712	2, 201, 394	337, 163	510, 875
1881	1, 077, 217	124, 477	402, 640	51, 633	176, 110
1882	1, 473, 109	147, 416	224, 052	30, 013	177, 429
1883	1, 115, 386	113, 349	....	....	113, 349
1884	2, 204, 070	219, 957	2, 036	204	220, 161

a Not enumerated until 1871.

Copper imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Bars, ingots, and pigs.		Old, fit only for remanufacture.		Old, taken from bottoms of Ameri- ships abroad. (*b*)		Plates not rolled.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*	
1867	1, 635, 953	$287, 831	569, 732	$81, 930	....	......	....	....
1868	61, 394	6, 935	318, 705	42, 652	....	......	....	....
1869	13, 212	2, 143	290, 780	34, 820	....	......	....	....
1870	5, 157	418	255, 386	31, 931	....	......	....	....
1871	3, 316	491	369, 634	45, 672	....	......	430	$129
1872	2, 638, 589	578, 965	1, 144, 142	178, 536	....	......	148, 192	33, 770
1873	9, 697, 608	1, 984, 122	1, 413, 040	255, 711	32, 307	$4, 913	550, 431	97, 888
1874	713, 935	134, 326	733, 326	137, 087	9, 500	930	....	....
1875	58, 475	10, 741	396, 320	55, 564	11, 636	1, 154	8	4
1876	5, 281	788	239, 987	35, 545	10, 304	1, 981	5, 467	600
1877	230	30	219, 443	28, 608	41, 482	5, 156	....	....
1878	1	......	198, 749	25, 585	....	6, 004	....	....
1879	2, 515	352	112, 642	11, 997	11, 000	1, 107	27, 074	4, 496
1880	1, 242, 103	206, 121	695, 255	91, 234	....	......	120	11
1881	219, 802	36, 168	541, 074	63, 383	14, 680	1, 504	20	3
1882	6, 200	836	508, 901	59, 629	16, 075	1, 629	....	....
1883	....	....	330, 495	36, 166	9, 415	666	....	....
1884	*c* 542	107	149, 701	12, 099	....	554	....	....

b Not enumerated until 1873.

c Includes "plates not rolled."

Copper imported and entered for consumption in the United States, &c.—Continued.

Fiscal years ending June 30—	Plates rolled; sheets, pipes, etc.		Sheathing metal, in part copper. (*a*)		Manufactures not otherwise specified.	Total value.
	Quantity.	Value.	Quantity.	Value.	Value.	
	Pounds.		*Pounds.*			
1867	....	$1,101	220,889	$37,717	$15,986	$424,565
1868	....	1	101,488	18,852	21,492	89,932
1869	....	39	43,669	6,592	43,212	86,800
1870	....	2,039	....	....	485,220	519,608
1871	....	7,487	....	....	668,894	722,673
1872	....	18,895	....	....	1,007,744	1,817,910
1873	....	4,514	....	....	869,281	3,216,429
1874	....	27	282,406	50,174	125,708	448,252
1875	....	617	136,055	23,650	35,572	127,272
1876	....	326	18,014	2,903	29,806	71,949
1877	....	203	110	22	41,762	75,761
1878	....	1,201	647	55	35,473	68,318
1879	....	786	300	20	39,277	58,035
1880	....	4,134	6,044	693	130,329	432,522
1881	....	82	39,520	4,669	284,509	390,318
1882	5,855	1,551	....	....	77,727	141,372
1883	2,842	379	6,791	1,047	40,343	78,601
1884	6,529	2,330	19,637	926	55,274	71,290

a Does not include copper sheathing in 1867, 1868, and 1869.

◆

Brass imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Bars and pigs.		Old, fit only for remanufacture.		Not otherwise provided for.	Total. value.
	Quantity.	Value.	Quantity.	Value.	Value.	
	Pounds.		*Pounds.*			
1867	....	$3,099	....	$26,468	$170,873	$200,440
1868	31,104	2,071	120,913	11,699	181,114	194,883
1809	33,179	2,457	131,640	10,838	198,310	211,605
1870	54,108	3,791	98,825	6,918	49,845	60,554
1871	28,453	2,803	438,085	37,922	13,659	54,384
1872	17,963	1,664	829,964	73,098	23,738	98,500
1873	56,656	7,147	699,478	71,494	114,767	193,408
1874	253	19	682,151	64,848	350,266	415,133
1875	370,273	38,867	124,285	12,786	273,873	325,526
1876	....	....	618,191	54,771	232,870	287,641
1877	....	....	689,633	59,402	207,642	267,044
1878	....	....	713,171	57,551	205,209	262,760
1879	950	49	485,354	32,278	232,030	264,357
1880	....	....	958,590	75,093	339,131	414,224
1881	85,370	11,202	1,615,402	151,541	331,506	494,249
1882	30,769	3,168	2,954,148	263,891	400,477	668,136
1883	6,380	559	1,015,345	84,786	485,321	570,666
1884	1,611	445	508,923	40,766	429,224	470,435

EXPORTS.

The wide fluctuations in the quantities of copper, copper ore, and manufactured copper exported for a series of years are exhibited in the following tables:

Copper and copper ore of domestic production exported from the United States, 1864 *to* 1884 *inclusive.*

[Cwts. are long hundredweights of 112 pounds.]

Fiscal years ending June 30—	Ore.		Pigs, bars, sheets, and old.		Value of manufactured.	Total value.
	Quantity.	Value.	Quantity.	Value.		
	Cwts.		*Pounds.*			
1864	109, 581	$181, 298	102, 831	$43, 229	$208, 043	$432, 570
1865	225, 197	553, 124	1, 572, 382	709, 106	282, 640	1, 544, 870
1866	215, 080	792, 450	123, 444	33, 553	110, 208	936, 211
1867	87, 731	317, 791	*a* 4, 637, 867	303, 048	171, 062	791, 901
1868	92, 612	442, 921	1, 350, 896	327, 287	152, 201	922, 409
1869	121, 418	237, 424	1, 134, 360	233, 932	121, 342	592, 698
1870	*a* 19, 198	537, 505	2, 214, 658	385, 815	118, 926	1, 042, 246
1871	*a* 54, 445	727, 213	581, 650	133, 020	55, 198	915, 431
1872	35, 564	101, 752	267, 868	64, 844	121, 139	287, 735
1873	45, 252	170, 365	38, 958	10, 423	78, 288	259, 076
1874	13, 326	110, 450	503, 160	123, 457	233, 301	467, 208
1875	*a* 51, 305	729, 578	5, 123, 470	1, 042, 536	43, 152	1, 815, 266
1876	15, 304	84, 471	14, 304, 160	3, 098, 395	343, 544	3, 526, 410
1877	21, 432	109, 451	13, 461, 553	2, 718, 213	195, 730	3, 023, 394
1878	32, 947	169, 020	11, 297, 876	2, 102, 455	217, 446	2, 488, 921
1879	23, 070	102, 152	17, 200, 739	2,751, 153	79, 900	2, 933, 205
1880	21, 623	55, 763	4, 206, 258	667, 242	126, 213	849, 218
1881	9, 958	51, 499	4, 865, 407	786, 860	38, 036	876, 395
1882	25, 936	89, 515	3, 340, 531	565, 295	93, 646	748, 456
1883	112, 923	943, 771	8, 221, 363	1, 293, 947	110, 286	2, 348, 004
1884	386, 140	2, 930, 895	17, 044, 760	2, 527, 829	137, 135	5, 595, 859

a Evidently errors in quantities.

Value of copper, brass, and manufactured copper exported from the United States to 1863, *inclusive.*

Fiscal years ending September 30 until 1842, and June 30 since.	Value.	Fiscal years ending September 30 until 1842, and June 30 since.	Value.
1791	$493	1833	$203, 880
1803	6, 233	1834	198, 273
1804	8, 654	1835	69, 791
1805	12, 977	1836	72, 991
1806	25, 340	1837	91, 724
1807	12, 742	1838	81, 363
1808	4, 031	1839	81, 334
1809	3, 095	1840	86, 954
1810	17, 426	1841	72, 932
1811	9, 282	1842	97, 021
1812	2, 644	1843 (nine months)	79, 234
1813	....	1844	91, 446
1814	....	1845	94, 736
1815	366	1846	62, 088
1816	16, 152	1847	64, 980
1817	8, 765	1848	61, 463
1818	33, 379	1849	66, 203
1819	12, 721	1850	105, 060
1820	18, 547	1851	91, 871
1821	26, 694	1852	103, 039
1822	36, 974	1853	108, 205
1823	16, 768	1854	91, 984
1824	26, 981	1855	690, 766
1825	30, 472	1856	534, 846
1826	60, 083	1857	607, 054
1827	52, 341	1858	1, 985, 223
1828	60, 452	1859	1, 048, 246
1829	129, 647	1860	1, 664, 122
1830	36, 601	1861	2, 375, 029
1831	55, 755	1862	1, 098, 546
1832	105, 774	1863	1, 026, 038

Value of brass, and manufactures of, exported from the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1867	$12,864	1876	$256,974
1868	16,841	1877	3 7,817
1869	40,063	1878	589,451
1870	169,997	1879	200,871
1871	210,816	1880	183,468
1872	229,458	1881	216,057
1873	494,575	1882	322,439
1874	503,531	1883	287,847
1875	1,000,629	1884	301,014

Exports of copper and copper ore of domestic production and of domestic manufactures of copper in the calendar years (ending December 31) 1883 *and* 1884.

Exports.	1883.		1884.	
	Quantity.	Value.	Quantity.	Value.
Copper ore, long tons	12,253	$1,971,581	33,672	$4,366,910
Ingots, bars, and old copper, pounds	18,206,187	2,784,816	30,321,295	3,872,456
Sheets, pounds			83,864	16,323
All manufactures of copper	....	126,208	....	112,505
Total	....	4,882,605	....	8,368,174

The exports of copper during the calendar year 1884 were 30,321,295 pounds, in the form of ingots, bars, and old copper. The bars are almost exclusively Arizona product, being the black or blister copper as made at the furnaces. From a comparison of the total Arizona output and of the quantity of copper shipped to American refining works, and the small amounts taken by consumers direct, it may be estimated that 3,700,000 pounds were exported in that form. The refiners and the Boston and Colorado Works exported 4,600,000 pounds, coming, of course, from a variety of sources. The Lake companies sent out 18,000,000 pounds between May, 1884, and January, 1885, thus leaving about 4,000,000 pounds as the export of second hands. The copper contents of the 33,672 tons of ore and matte exported are estimated to have been 28,000,000 pounds, almost all of it Montana product, thus making the shipments to foreign countries in all 58,300,000 pounds. The quantity apparently available for home consumption is therefore 83,300,000 pounds, from which must be deducted the amount of Colorado, California, and desilverizers' product used for making bluestone. It may be fairly stated, then, that our home consumption was called upon to deal with about 80,000,000 pounds of copper. This it has undoubtedly done, since the supply at the end of the year was by no means excessive. It is certainly a highly encouraging feature that our manufacturers took so large a quantity of metal in spite of the dull times. While the demand for machinery, brass castings, and alloys was probably below the average of former years, the quantity consumed, notably for electrical purposes and for domestic utensils and ornaments, was certainly very much larger. A very encouraging point has been the growing favor of hard-drawn copper wire for telegraph lines. One telegraph company, judging from the mileage of this class of wire and its average weight per mile, must have alone used fully 1,000,000 pounds. Hard-drawn copper wire is very highly spoken of by electricians as a material for the transmission of messages by modern methods, and if the great promises of the trials made thus far are borne out by long continued experience, a demand will be created which will be highly beneficial to the metal. There has been a good deal of agitation, largely misdirected, looking to the wider introduction of copper as a material for roofing, water service, etc. There is some future for the use of the metal in this direction if low prices continue, but it must necessarily be a matter of slow growth, not likely to affect consumption very materially in the next few years.

The export of manufactured goods has as yet made very little headway in spite of the fact that our manufacturers now have a very cheap raw material, and their works are splendidly equipped to produce cheaply a large variety of very tastefully made goods. There can be no question that this is a field worthy of cultivation and in which American manufacturers can develop a large and growing outlet.

THE COPPER MARKETS.

The following table summarizes the highest and lowest prices obtained for Lake copper monthly in the New York market from 1860 to 1884, both inclusive:

Highest and lowest prices of Lake Superior ingot copper, by months, from 1860 *to* 1884.

[Cents per pound.]

Years.	January.		February.		March.		April.		May.		June.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1860	24	23½	24	23¾	23¾	23	23½	23	23¼	22½	22½	21¾
1861	20	19	19½	19	19¾	19¼	19¾	19	19¼	19¾	19	18
1862	28	27	28	25	25	23	23	21½	21½	20¾	23	20¾
1863	35	31	37	35	37	31	31	30	30½	30	30½	30
1864	41¼	39	42	41¼	42½	41½	44	42½	44	43	49	44
1865	50½	46	46	44	44½	34	35	34	34	30	30½	28½
1866	42	38	38	35½	35½	29½	30	28½	31	29	33	31
1867	29¼	27	27¾	27½	27½	24	24½	23½	24¼	24	24½	24
1868	23½	21½	24	22½	24	23¼	24¼	23¼	24¼	24	24	23⅛
1869	26¼	23¾	27	26	26¾	24	24	23¼	24¼	23¾	23¾	22
1870	22	21⅛	21¼	20⅞	20¾	19	19¾	19¼	19½	19	20⅝	19
1871	22⅞	22	22⅜	21⅞	22	21½	21¾	21¼	21¾	21⅜	21½	21¼
1872	28½	27⅛	28⅜	28¼	30½	28⅜	44	30½	42	36	34¾	33
1873	35	32½	35	34	35	34½	34½	33½	33½	32	31½	29⅛
1874	25	24½	25	24⅛	24¾	24	25	24¾	25	24½	24¾	24¼
1875	23½	21½	22¾	21¾	21¾	21½	21¾	21½	23¼	22⅝	23	23
1876	23¼	23	22⅞	22½	22¼	22	22⅜	22	22⅛	21	21	19¼
1877	19½	19	20½	19½	19½	19	19½	19¼	19¼	19	19⅜	19
1878	17⅝	17¼	17½	17⅛	17⅛	16⅞	17	16⅞	16¾	16¼	16⅜	16¼
1879	16	15½	15½	15½	15¾	15¾	16	15¾	16¼	16	16¼	16⅛
1880	25	21⅜	24½	24	24	22¾	22½	21	21	18	18½	17⅞
1881	19⅜	19⅛	19⅜	19⅛	19⅜	19	19	18¾	18⅞	18¼	18¼	18⅜
1882	20⅜	20¼	20	19	19¼	18⅞	18⅞	17⅞	18¼	18	18¼	18
1883	18⅛	18	17⅞	17¾	17⅝	17⅛	16	15¾	16	15⅞	15⅞	15
1884	15	14⅞	15	14⅞	16	14⅞	15	14½	14¼	14⅛	14¼	14

Highest and lowest prices of Lake Superior ingot copper, &c.—Continued.

Years.	July.		August.		September.		October.		November.		December.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1860	21¾	21½	21½	21½	22	21¼	22	21½	21½	20¼	20¼	19¾
1861	18	17½	19	17¾	20¼	19	20¼	20	22½	20¼	27	22½
1862	24½	22½	24½	24	27	24¼	32⅞	27	32⅞	30½	31½	30½
1863	32	29	31	29	32¼	31	34½	32¼	38½	34½	38¾	38½
1864	55	49	52½	50	52½	47½	48	47	49	47	50	48½
1865	30¼	28	32	30½	32¾	31½	33	32½	45½	33	45½	39¼
1866	33½	31	31	30	31½	30¾	31	30¾	30¾	26½	29	26½
1867	26	24	26¼	25¾	27¼	26¼	26¾	22¾	23	22¾	23	21½
1868	24½	23⅛	24¼	24	24	23¾	24	23	24	22½	24½	23¾
1869	22¼	21⅞	23⅛	21⅞	23	22	22¾	22	22½	22	22	21½
1870	20½	20⅜	21⅜	20⅛	21½	20¾	21¾	21½	23⅜	21¾	22⅝	22¼
1871	22¼	21⅝	23	22⅜	23⅞	22⅞	23⅞	23¼	24¼	23¼	27	24½
1872	34	33	35	32½	35¼	33	34¾	31¼	32¼	30¾	32½	30½
1873	29	26⅝	27½	27	27	25½	25½	24	24	21	25	23
1874	24¼	20	21	19	21¼	21	22¼	21¼	23¾	22¼	23¼	23¼
1875	23	22⅝	23⅜	23	23⅞	23⅛	23¼	23	23¼	23	23⅜	23⅜
1876	20	19½	19½	18¾	21	18¾	21¼	20½	20½	20	20	19⅝
1877	19¼	19	19	17⅞	18½	17⅞	18	17¾	17¾	17⅝	17¾	17⅛
1878	16¼	16	16	16	16¼	16	16	15½	15⅞	15½	16	15⅞
1879	16⅛	16	16⅜	16	17	16¼	21½	18	21¾	21	21½	21
1880	18⅞	18½	19⅛	19	18⅞	18¾	18⅞	18¾	18⅞	18¾	19⅛	18⅞
1881	16½	16	16⅝	16⅜	18⅛	16¾	18⅜	18	19	18⅛	20⅜	19¼
1882	18¼	18⅛	18¼	18⅛	18¼	18	18¼	18	18⅛	18	18	17⅞
1883	15⅛	15	15	15	15¼	15⅛	15¼	15⅛	15	14⅞	15	14⅞
1884	14⅛	13⅞	14	13⅞	13⅛	13	13⅛	12⅞	13	12½	12⅛	11

1883.—During 1883 the prices of Lake Superior copper and of good ordinary Western brands varied as follows:

Prices of copper in 1883.

Months.	Lake copper in New York.		Good ordinary Western in New York.		Average monthly price of Chili bars in London.
	Highest.	Lowest.	Highest.	Lowest.	
	Per pound.	*Per pound.*	*Per pound.*	*Per pound.*	*Per long ton.*
January	$0 18½	$0 18	$0 17	$0 16	£66 5 6
February	17⅞	17¾	16½	15¾	65 8 9
March	17⅝	*a* 17⅛	15¾	15⅛	65 13 8
April	16	15¾	15	14½	65 11 18
May	16	15⅞	15	14½	62 9 2
June	15⅞	*b* 15	14⅞	14	64 0 2
July	15⅛	15	14⅛	14	63 17 9
August	15	15	14⅛	14	63 16 0
September	15¼	15⅛	14¼	14⅛	63 12 3
October	15¼	15⅛	14¼	14⅛	61 17 6
November	15	*b* 14⅞	14⅛	14	60 8 6
December	15	14⅞	14⅛	14	58 6 6

a For export, 16 cents. *b* For home consumption, 15 cents.

In the early part of January manufacturers contracted with Lake companies for the purchase of ten to eleven million pounds of copper, approximately two to three months' demand, at 18 cents. The result was that sellers of other brands began to show much anxiety in disposing of their product, and a decline was precipitated, which more and more widened the gap between the quotations of Lake and of other brands. This brought out from week to week small lots of Lake to be resold by those manufacturers who desired to realize a profit by using Western copper. Under the pressure thus brought to bear, Lake copper slowly receded, and in turn forced down the price of competing brands. This decline was rendered more rapid still by the efforts of sellers of unknown brands to obtain a foothold, and by the throwing upon the market of Western copper by bankers who had made advances upon it. The eagerness of holders to place their metal naturally increased the reluctance of buyers, who were confirmed in their position by the fact that the demand for manufactured goods was slack and had been made worse by the competition for trade by makers, of whom each believed himself to be capable of outbidding others because of low purchases of raw material. The demoralization in the latter spread to the manufacturing trade, which only aggravated the evil. In the middle of March the Lake companies sold about 7,000,000 pounds of copper for export, and when this movement did not seem to check the decline or shake the position of buyers, they suddenly, in the beginning of April, began to be free sellers at 16 cents. A considerable quantity of copper was placed, but there was not, it appears, a pool of sellers negotiating with the principal buyers. The first effect of this sudden turn was to force a few small holders to realize at lower figures. Since then Lake was pretty firmly held at 15$\frac{7}{8}$ cents, though it slightly recovered, the quantities offered being slight in April and May. In June the Lake companies again came forward, contracting for the delivery of 20,000,000 pounds to consumers at 15 cents. Meanwhile other brands dropped off, particularly those not having a recognized standing or marketed under special circumstances. The quotations given above are for fair brands; they are higher, in some cases as much as one-quarter to three-eighths of a cent, than the figures which have formed the basis of actual transactions. They are lower, on the other hand, than the prices readily obtained for certain special brands made of black copper produced from the pure oxidized ores, notably of Arizona, and which range only one-half of a cent lower than Lake copper. It is striking that the differences should be so great, being in some cases as much as 1$\frac{1}{2}$ cents per pound. There can be no doubt that, intrinsically, copper refined carefully and having no grave quantities of impurities is worth more than the difference in quotations would indicate. Chili bars containing only 96 per cent. of copper have been occasionally sold in this market during the past ten years, and generally the difference was not more than 1$\frac{1}{2}$ cents per pound.

July passed by quietly, though without any evidences of weakness, a surplus of outside brands being marketed abroad, so that early in August the latter developed more strength. There were also during that month some export sales of Lake copper at prices equivalent to those ruling in this market, and in spite of a pretty steady decline abroad there was a better feeling generally throughout September. In October, while waiting for developments concerning the coming contracts between the Lake companies and the consumers, some of the latter were forced to come into the market for small lots, which accordingly realized slightly higher prices. In the middle of the month it was given out that the old contracts at 15 cents had been extended to cover the balance of the year, and somewhat later it was announced that the arrangement in reality covered the period to April, 1884, involving the sale of, roughly, 20,000,000 pounds. It was understood that much of this copper was to be delivered at buyers' factory, a step probably taken to make the exchange of other brands for Lake on a falling market more difficult.

The last two months of the year were as usual without events of any significance. There was very little copper pressing on the market, and on the other hand buyers were few and their purchases unimportant. Very little, if any, Lake copper was thrown upon the market by manufacturers.

1884.—During this year the fluctuations in the prices of Lake copper and of good Western brands were as follows:

Prices of copper in 1884.

Months.	Lake copper in New York.		Good ordinary Western brands in New York.		Average monthly price of Chili bars in London.	Average monthly price of copper ore in Liverpool, 25 per cent.	Average monthly price of precipitate in Liverpool.
	Highest.	Lowest.	Highest.	Lowest.			
	Per lb.	*Per lb.*	*Per lb.*	*Per lb.*	*Long ton.*	*Per unit.*	*Per unit.*
January	$0 15	$0 14⅞	$0 14⅛	$0 13⅞	£58 0 6	£0 11 3	£0 11 10
February	15	11⅞	14⅛	13⅞	56 1 3	11 0	11 10⅛
March	15	*a* 14⅞	13⅞	13⅜	54 15 6	10 10	11 4
April	15	*b* 14½	13⅝	13⅜	56 3 10	10 9	11 2½
May	14¼	14⅛	13¼	13⅛	56 10 0	11 11	11 8⅞
June	14¼	14	13¼	12⅞	54 18 0	10 6½	11 3⅛
July	14⅛	13⅞	13	12¾	54 7 3	10 3¾	10 11¼
August	14	13⅞	12⅞	12½	54 9 6	10 1	10 10¾
September	13⅛	*c* 13	12½	12	54 4 5	10 2	10 9⅛
October	13⅛	12⅞	12	11¾	53 15 7	10 1½	10 9¼
November	13	12½	11¾	11⅛	52 5 0	9 9	10 5½
December	12⅛	11	11⅛	10½	48 18 3	9 1½	9 11⅛

a For export, 13 cents. *b* For home consumption, 14 cents. *c* For home consumption, 13 cents.

Since the English quotations have become of such direct importance to American copper miners, the following table, showing a comparison of values in 1884 with former years, is of interest:

Average values in England.

Years.	Chili bars.	Ore, 25 per cent.	Precipitate.
	Long ton.	*Per unit.*	*Per unit.*
1880	£62 10 0	£0 12 9	£0 12 11
1881	16 10 0	12 6	13 $8\frac{3}{16}$
1882	66 17 0	13 6¾	13 $10\frac{1}{16}$
1883	63 5 10	12 4½	12 $10\frac{1}{16}$
1884	54 9 1	10 5½	11 1

With a view to illustrating the difference in quotations between ordinary Chili bars, the speculative article, and one of the best brands, ranking with Lake copper, regularly quoted in England, the prices at the end of each month during the year 1884 are given:

Comparison of prices in England.

Dates.	Chilibars.	Wallaroo.	Difference.
December 31, 1883	£58	£67	£9
January 31, 1884	56⅞	65½	8⅝
February 28, 1884	55½	64	8½
March 31, 1884	54	62½	8½
April 30, 1884	56⅜	64½	8⅛
May 31, 1884	56	64	8
June 30, 1884	54⅛	62	7⅞
July 31, 1884	55	62	7
August 31, 1884	54	61	7
September 30, 1884	54	61	7
October 31, 1884	52⅝	61	8⅜
November 30, 1884	50¾	59	8¼
December 31, 1884	47¼	56½	9¼

The year opened quietly, with little pressure to sell on the one hand, and comparatively very little inquiry. The Lake companies declined fair foreign orders, and January closed a shade firmer. February was exceedingly dull, nothing whatever occurring to change values or to indicate any early movement upward or downward. Refiners of other material suffered to some extent from the usual winter curtailment of the supply of black copper, ore, and matte, and showed less tendency to anticipate consumers' wants or force metal abroad. When, however, in March it became known that the Lake companies had contracted abroad for the delivery of 7,500 tons at 13 cents, the sellers of other brands began to show more anxiety, and the usual tactics of placing as much copper as possible before the coming Lake sale were followed, the effect being a gradual decline in the price of these brands. This again reflected back upon Lake copper, which began to weaken, and forced the companies to name 14 cents as the basis of their contracts with consumers, involving about 12,000,000 pounds for delivery during the summer. In spite of the financial troubles of May that month passed quietly, the only feature being the continued weakening of outside brands. In June it seemed for a time that the floods of the Colorado and Rio Grande rivers would, by cutting off the coke supply to some of the Arizona producers, diminish the output of that Territory, but the damages to the railroads were promptly repaired and had little effect. July was quiet, and there was comparatively little selling of Lake copper on the part of manufacturers who were replacing it by cheaper Western brands. The latter showed considerable weakness during August, a month during which the usual maneuvering between the companies and the consumers was going on. Early in September the contracts were closed on the basis of 13 cents, the quantity involved being about 10,000,000 pounds. The other brands promptly followed the drop; but the sellers of this class of metal sought relief by marketing as much as possible abroad, the export sales of Arizona refined and bar aggregating fully 1,500 tons. Contracts were also closed for 9,000 tons of Montana ore in England. The Lake companies meanwhile declined export orders at 12½ cents, but in the following month they were selling at 12⅜ and 12¼.

In sympathy with the decline abroad the market here showed an unbroken tendency downward and the contracting of heavy quantities of Montana matte in England—the Anaconda, for instance, selling its 1885 product of about 7,500 tons matte based on quotations of best selected—did not tend to mend figures. The Calumet and Hecla fire in October had no effect upon the market, and in the beginning of December the Lake companies met the decline by selling to consumers at 12 cents. They were at the same time heavy sellers in Europe, contracting to deliver 7,500 tons, the copper being taken evidently on speculation by a large banking concern, on the basis of Chili bars, which began to show a heavy decline early in December. These sales were made allowing only an advance of £4 per ton for Lake over Chili bars, which the purchasers are marketing at about £7 over Chili bar quotations. Toward the end of the month it was announced that the Lake companies had made a contract for the first five months of 1885 with domestic consumers, the quantity involved being about 2,000,000 pounds per month. The price to be paid is based on the average quotation of Chili bars for the preceding month for the dates ranging between the 10th and the 25th. The lowest price is to be 10½ cents, when Chili bars have averaged £48 or under, the price to advance one-tenth of 1 cent for every 10*s*., increased average until £53 or over is reached, when the maximum price is to be 11½ cents. It is understood that under this arrangement the January price was fixed at 10.60 cents. The sale, it is stated, is coupled with the condition that the purchasers are not to use any other brands of copper. It would appear, therefore, that every effort is being made to secure to the pool the customers it holds, the sales for export being invariably made with the proviso that none of the copper is to be returned to this country, while domestic buyers are enjoined from placing copper once bought upon the open market. The latter step was evidently taken to protect the market against resales by manufacturers who, especially during 1882 and 1883, frequently replaced Lake bought by other cheaper brands of Western copper, throwing the Lake upon the market.

A great event during the year was the withdrawal of the Quincy Mining Company from the pool, and the appeal on the part of the other members of it to the courts for an injunction, which was denied. From the papers in the suit and from published statements growing out of it considerable light was thrown upon the character of the pool. It appears that on the 14th of February an agreement was made, substantially, so far as is known, modeled after similar earlier covenants, designating the Calumet and Hecla Company as selling agent of the combined product of the Calumet and Hecla, Quincy, Atlantic, Central, Allouez, Franklin, Pewabic, Huron, Conglomerate, and Copper Falls mines.

The only large company not a member of the pool was the Osceola, which, however, sold to Waterbury manufacturers on the basis of the pool sales. The agreement was entered into till the 1st of January, 1885, but subsequently, on August 20, was extended to March 31, 1886. One clause of the agreement, not generally known, was that the Calumet and Hecla Company had the right to temporarily withhold from apportionment 10 per cent. of the pool sales as a fund to be used at the discretion of the Calumet and Hecla Company for the purpose of relieving any of the small companies from any strain caused by the accumulation of copper on their hands or for the purchase of Lake copper in the market.

In reply to an inquiry from the Quincy Company the Calumet and Hecla Company informed the Quincy that 2,000 tons of special size cakes had been sold for export in October, November, and December, but that owing to inability to deliver the October portion the dates of delivery were changed to November, December, and January, 1885, the price to be paid to be the average price of Chili bars in each of the months named, with £4 added.

It is reported that the November settlement showed that for its share of the export sale of that month it received 11⅝ cents per pound of copper. The Quincy accepted offers of 12 cents per pound for 1,200 tons for export, and it was then that proceedings against it were begun. To-day, therefore, two large companies, the Quincy and the Osceola, have withdrawn from the combination, which, so far as its control of the domestic market is concerned, has outlived its usefulness, chiefly on account of the competition of the Western mines, and has since been entirely abandoned.

The prices realized for the copper produced vary somewhat. The following table, compiled from the reports of the different mines to the shareholders, exhibit these fluctuations and furnish a fair basis to estimate the average price obtained during the year:

Prices realized for Lake Superior copper in 1883.

Mines.	Sales.	Average price.
	Pounds.	*Cts. per lb.*
Allouez	1, 751, 377	15. 13
Franklin	3, 418, 456	15. 66
Atlantic	2, 385, 585	15. 08
Pewabic	1, 239, 740	15. 91
Central	1, 125, 910	15. 08
Huron	647, 787	15. 69

THE PRINCIPAL FOREIGN PRODUCERS.

Since American producers have begun to assume the role of more than occasional sellers in foreign markets and have come into direct competition with the mines of almost every quarter of the globe, the question constantly arises how far are our foreign rivals capable of holding their ground, what point must be reached in the decline before an enforced restriction of output is reached, and to what extent our own mines will share in that cessation of work. We know that the English mines will practically cease to exert any influence, that the Australian, Canadian, and Venezuelan producers must go to the wall should prices for ore and regulus remain below 10*s.* per unit for any length of time; on the other hand that the great pyrites mines of Spain and Portugal can live, that the Cape of Good Hope product will continue, that the Mansfeld district in Germany will contrive to make ends meet, but we have little positive information, unfortunately, concerning the heaviest copper shipping country, Chili. In the absence of any precise knowledge concerning the cost of production in that country, or of the capacity of the rich owners of the leading mines to bear up under heavy losses, it is only possible to repeat the general impression in well informed quarters that prices below £50 in London press very heavily upon the copper industry of Chili. On some of the points at issue data will be found in the following review of the development of the copper industry in the leading producing countries.

Aside from the interest which attaches to the affairs of producers in foreign countries, since we have become their direct and most feared competitors, the markets of Great Britain, reflecting as they do the demand and supply of the world, have attained a new and direct significance because the prices paid for nearly one-half of the make of our country are based upon the daily quotations of Chili bars or of best selected. Every movement, every fluctuation in the world's markets is immediately felt by American producers, directly or indirectly.

Messrs. Henry Merton & Co. have compiled the following table of the copper production of the world, and have since its publication kindly completed some of the estimates when later returns were available. Some of the data have been changed and corrected by this office from information directly received from various quarters. The copper is in all cases credited to the source where it originated. Thus the contents of the pyrites shipped from Spain are included in the figures given for that country. The table as it stands reflects the results of the closest scrutiny and may be accepted as the most complete and accurate now available.

The copper production of the world, 1879 *to* 1883 *inclusive.*

Countries.	1883.	1882.	1881.	1880.	1879.
EUROPE.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Great Britain	2, 620	3, 464	3, 875	3, 662	3, 462
Spain and Portugal:					
Rio Tinto	20, 472	17, 389	16, 666	16, 215	13, 751
Tharsis	9, 800	9, 000	10, 203	9, 151	11, 324
Mason & Barry	8, 000	8, 000	8, 170	6, 603	4, 692
Sevilla	2, 026	1, 885	1, 340	1, 705	1, 360
Portugueza	2, 357	1, 700	1, 410	1, 000	770
Poderosa	1, 000	800	800	800	800
Germany:					
Mansfeld	12, 634	11, 536	10, 999	9, 800	8, 400
Other German	3, 568	3, 552	1, 743	1, 000	600
Austria	572	474	474	500	255
Hungary	661	661	800	900	1, 019
Sweden	800	798	995	1, 074	800
Norway	2, 630	2, 590	2, 640	2, 426	2, 412
Italy	1, 600	1, 400	1, 480	1, 380	1, 140
Russia	3, 000	3, 000	3, 000	3, 081	3, 081
Total Europe	71, 740	66, 249	64, 595	59, 297	53, 866
NORTH AMERICA.					
United States	51, 574	40, 467	32, 000	27, 000	23, 000
Canada	1, 055	500	500	50	50
Newfoundland:					
Bett's Cove	1, 053	1, 500	1, 718	1, 500	1, 500
Mexico	489	401	333	400	400
Total North America	54, 171	42, 868	34, 551	28, 950	24, 950
SOUTH AMERICA.					
Chili	41, 099	42, 909	37, 989	42, 916	49, 318
Bolivia					
Corocoro	4, 000	3, 259	2, 655	2, 000	2, 000
Peru	395	440	615	600	600
Venezuela					
New Quebrada	4, 018	3, 700	2, 823	1, 800	1, 597
Argentine Republic	293	800	307	300	300
Total South America	49, 805	51, 108	44, 389	47, 616	53, 815
AFRICA.					
Algiers	600	600	600	500	500
Cape of Good Hope:					
Cape Copper Company	5, 975	5, 716	3, 467	4, 739	4,328
Total Africa	6, 575	6, 316	4, 067	5, 239	4, 828
ASIA.					
Japan	5, 000	2, 800	1, 900	1, 900	1, 900
Total Asia	5, 000	2, 800	1, 900	1, 900	1, 900
Australia	12, 500	8, 512	10, 000	9, 700	9, 500

RECAPITULATION.

Europe	71, 740	66, 249	64, 595	59, 297	53, 866
North America	54, 171	42, 868	34, 551	28, 950	24, 950
South America	49, 805	51, 108	44, 389	47, 616	53, 815
Africa	6, 575	6, 316	4, 067	5, 239	4, 828
Asia	5, 000	2, 800	1, 900	1, 900	1, 900
Australia	12, 500	8, 512	10, 000	9, 700	9, 500
Total	199, 791	177, 853	159, 502	152, 702	148, 859

Great Britain.—The decline in the production of the British mines has been continued, and they have practically ceased to exert any influence.

Production of copper in Great Britain.

Years.	Ore.	Copper.	Years.	Ore.	Copper.
	Long tons.	*Long tons.*		*Long tons.*	*Long tons.*
1860	362. 696	15, 968	1876	79, 252	4, 694
1865	198, 298	11, 888	1877	73, 143	4, 486
1870	106, 698	7, 175	1878	56, 094	3, 952
1871	97, 129	6, 280	1879	51, 035	3, 462
1872	91, 893	5, 703	1880	52, 118	3, 662
1873	80, 188	5, 240	1881	52, 556	3, 875
1874	78, 521	4, 981	1882	52, 810	3, 464
1875	71, 528	4, 323	1883	46, 820	2, 620

The official figures for 1884 show a slight increase, to 3,300 tons, as the yield of the Cornish mines.

Great Britain, however, handles more than half the copper produced in the world, and the figures relating to that trade are of the greatest importance.

British imports and exports of copper.

Years.	Imports of—		Total imports.	Exports.
	Bars, cakes, and ingots.	Copper in ores and furnace products.		
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
1860	13, 142	13, 715	26, 857	26, 117
1865	23, 137	23, 922	47, 059	41, 398
1870	30, 724	27, 025	57, 749	53, 006
1871	33, 228	23, 671	56, 899	56, 633
1872	49, 000	21, 702	70, 702	53. 195
1873	35, 840	26, 756	62, 596	55, 716
1874	39, 906	27, 894	67, 800	59, 742
1875	41, 931	29, 483	71. 414	51, 870
1876	39, 145	36, 191	75, 336	52, 468
1877	39, 743	53, 582	93, 325	54, 088
1878	39, 360	48, 212	87, 572	55, 001
1879	46, 670	50, 421	97, 091	62, 412
1880	36, 509	56, 225	92, 734	59, 482
1881	32, 170	54, 057	86, 227	61, 689
1882	35, 509	58, 366	93, 875	55, 683
1883	35, 653	63, 493	99, 146	59, 350
1884	39, 815	63, 091	112, 906	64, 691

The following figures from the Board of Trade returns for the seven years since 1878 show in detail the form in which the copper is brought into Great Britain and in what form it is exported:

Imports of copper into Great Britain from 1878 *to* 1884 *inclusive.*

Character.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Pure in pyrites	14, 443	12, 040	16, 446	13, 551	15, 672	15, 016	14, 077
Pure in precipitate	13, 173	18, 159	18, 205	18, 619	17, 935	23, 645	21, 738
Pure in ore	15, 441	13, 173	14 976	15, 396	15, 489	15, 880	24, 842
Pure in regulus	5, 155	7, 049	6, 598	6, 491	9, 270	8, 952	12, 434
Bars, cakes, etc	39, 360	46, 670	36, 509	32, 170	35, 509	35, 653	39, 815
Total	87, 572	97, 091	92, 734	86, 227	93, 875	99, 146	112, 906

Exports of copper from Great Britain from 1878 *to* 1884 *inclusive.*

Character.	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Raw English	17, 319	16, 370	15, 202	18, 737	12, 776	16, 777	17, 943
Sheets	12, 769	15, 402	16, 580	15, 960	15, 698	16, 071	20, 669
Yellow metal, at 60 per cent	8, 744	10, 042	10, 128	9, 939	10, 892	11, 918	11, 602
Brass, at 70 per cent	3, 450	2, 761	2, 677	3, 263	3, 499	3, 381	3, 735
	42, 282	44, 575	44, 587	47, 899	42, 865	48, 147	53, 949
Fine foreign	12, 719	17, 837	14, 895	13, 790	12, 818	11, 203	10, 742
Total	55, 001	62, 412	59, 482	61, 689	55, 683	59, 350	64, 691

Turning first to the imports of pyrites, we find the following table of the imports and their source since 1873 in the volume of the Mineral Statistics of Great Britain:

Imports of pyrites into Great Britain.

Years.	Norway.	Portugal.	Spain.	Germany.	Other countries.	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1873	67, 462	199, 559	246, 692	....	6, 634	520, 347
1874	41, 044	162, 569	294, 117	....	907	498, 637
1875	21, 820	165, 433	344, 019	....	6, 283	537, 555
1876	7, 688	56, 579	419, 068	....	21, 417	504, 752
1877	8, 564	149, 562	498, 977	....	22, 209	679, 312
1878	5, 773	136, 705	419, 561	....	12, 318	474, 357
1879	8, 485	82, 529	374, 505	....	15, 783	481, 302
1880	10, 952	166, 519	463, 199	8, 695	8, 684	658, 049
1881	6, 009	140, 079	379, 216	8, 412	8, 662	542, 378
1882	....	114, 132	497, 807	....	15, 761	627, 700
1883	1, 271	121, 137	473, 343	....	5, 537	601, 288
1884	....	....	....	....	....	563, 078

Spain and Portugal therefore practically monopolize the business. The following table exhibits the quantity of burned pyrites treated at the twenty-two metal extraction works, together with the quantities of metallic copper and gold and silver extracted by the Claudet process:

Metals extracted from burned cupriferous pyrites.

Years.	Ore.	Copper.	Gold.	Silver.
	Long tons.	*Long tons.*	*Ounces.*	*Ounces.*
1880	415, 567	15, 000	1, 043	246, 981
1881	396, 737	14, 000	1, 490	258, 463
1882	434, 427	15, 300	1, 500	400, 000
1883	439, 156	15, 370	1, 511	348, 210

Prof. G. Lunge, of Zurich, the great authority on the manufacture of sulphuric acid and soda, has made some interesting calculations based on statistical data, to show for what purposes and in what quantities sulphuric acid is made in England. These computations are of interest, as they bear directly upon the prosperity of the great Spanish pyrites mines, and trace the causes which have no mean influence upon that important supply of copper, the metal extracted from pyrites cinder. The following table contains the principal data:

Sulphuric acid produced in Great Britain.

Years.	Made from pyrites.	Pyrites acid used for manufacture of sulphate of soda.	Pyrites acid used for other purposes.	Acid made from brimstone.	Total acid made.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1878	747, 900	417, 406	330, 494	124, 271	872, 171
1879	716, 625	445, 265	271, 360	116, 884	833, 509
1880	771, 771	501, 612	270, 159	133, 653	905, 424
1881	736, 797	475, 724	261, 073	115, 599	852, 396
1882	806, 793	472, 151	334, 642	124, 742	941, 535
1883	815, 574	484, 252	331, 322	125, 064	940, 638

The principal quantity of sulphuric acid is therefore consumed in the manufacture of soda. The ammonia-soda processes, which avoid the use of sulphuric acid, have been looked upon as seriously threatening the pyrites mines by diverting from them their most important customer. It is not now denied that the new processes can produce soda cheaper than the old Leblanc process, but the latter has apparently obtained a new lease of life through the increased value of the hydrochloric acid, formerly a waste by-product, and the substitution of the one method of manufacturing soda by the other is not likely to progress with that resistless rapidity which was claimed for it not long ago. The other principal consumer of pyrites acid, taking almost all of the heavy quantities under "pyrites acid for other purposes" in the above table, is the great fertilizer industry, whose requirements, it will be noted, are subject to wide fluctuations. It strongly illustrates the interdependence of modern industrial mining and agricultural industries that an important source of the supply of copper should fluctuate through the intermediary of two other industries with the requirements of the farmers of Great Britain and other countries for fertilizers.

The Spanish pyrites companies, recognizing the danger that their market might be seriously curtailed, have aided the struggling Leblanc soda makers by reducing the price of sulphur in pyrites materially on the contracts renewed in 1884.

Imports of precipitate and regulus into Great Britain.

Countries.	1880.	1881.	1882.	1883.	1884.	Containing fine copper (estimated).
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Portugal	5, 358	8, 144	7, 301	8, 873	7, 161	22, 608
Spain	20, 482	21, 647	21, 398	28, 962	27, 621	
Chili	14, 659	8, 116	10, 882	6, 384	10, 699	4, 815
Other countries	4, 502	6, 309	9, 716	13, 509	16, 929	7, 618
Total	45, 001	44, 216	49, 297	57, 728	62, 410	....
Pure copper	24, 772	25, 110	27, 205	32, 597	34, 172	....

By far the greater quantity of the material enumerated as coming from the Peninsula is precipitate, only a comparatively small part of the product being "regulus" or "matte," as we are accustomed to call that furnace product. All of the Chili imports are regulus. Among the "other countries" the United States, of course, are beginning to take the leading part. For 1884 the quantity is estimated to have contained 2,722 long tons fine copper.

The third source of supply of the copper metallurgical industries of Great Britain is ore, from the following countries, as enumerated by the latest Board of Trade returns:

Imports of copper ore into Great Britain.

Countries.	Quantities.			Values.			Average value per ton.		
	1882.	1883.	1884.	1882.	1883.	1884.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*						
Italy	12,690	9,403	11,100	£82,822	£66,893	£53,146	£6.53	£7.11	£4.79
Venezuela	25,630	31,844	25,900	190,387	214,191	159,520	7.43	6.73	6.16
Bolivia	3,714	1,029	2,067	46,794	13,354	18,200	12.60	12.98	8.81
Chili	362	1,062	245	5,902	13,991	4,880	16.33	13.17	19.92
Cape of Good Hope	19,052	19,917	22,330	381,019	352,630	343,671	20.00	17.71	15.35
British North America	15,163	10,876	2,067	90,218	65,662	9,000	5.95	6.04	4.35
Other countries	26,652	31,748	60,505	238,162	368,895	789,627	8.93	11.65	13.05
Total ore	103,263	105,879	124,214	1,035,304	1,095,616	1,378,044	10.02	10.35	11.09
Total pure copper	15,489	15,880	24,842	....	....	....	......	......	......
Average percentage	15.00	15.00	20.00	....	....	....	......	......	......

In this instance, too, the official Board of Trade returns have not kept pace with the latest developments, and the most important shipments in 1884, those from the United States, disappear in "other countries." An estimate places the contents of fine copper at 11,023 long tons. For 1883 the special return already alluded to shows the receipts to have been 10,732 tons, almost exclusively the product of Montana, estimated to have contained 4,940 tons fine copper. Norway sent 3,382 tons, Portugal 1,822 tons, Spain 2,271 tons, Algeria 5,161 tons, South Australia 3,756 tons, and Peru 1,334 tons. The decline in the values of the low-grade ores is well illustrated in the above table. The richest material, of course, is dependent more upon grade, and the average value of the shipments from other countries is affected by the particularly high grade of the new American supply, much of which, too, was argentiferous.

The chief source of supply of black copper or "bars," averaging 96 per cent., is Chili, the United States having, however, begun to contribute copper in this form. Refined copper comes chiefly from Australia, going to London. The following figures will show how largely these two countries participate in furnishing the manufacturers of Great Britain with raw material:

Imports of copper, wrought and unwrought, into Great Britain.

Countries.	1880.	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Chili	24, 258	21, 019	22, 585	22, 799	22, 843
Australia	9, 406	9, 150	8, 152	9, 531	9, 329
Other countries	2, 845	2, 001	4, 772	3, 323	7, 643
Total	36, 509	32, 170	35, 509	35, 653	39, 815

The receipts from Australia were derived from the different colonies as follows in 1883: New South Wales, 6,729 tons; South Australia, 2,442 tons; Victoria, 261 tons; and Queensland, 98 tons. Among the "other countries," according to the special return of 1883, the United States occupied the first rank, with 1,866 tons; Spain contributing 437 tons, Peru 291 tons, and France, Turkey, Japan, Argentine Republic, and others, smaller quantities.

Messrs. James Lewis & Son, of Liverpool, estimate as follows the imports of other than Chili copper into Liverpool and Swansea during the years 1882, 1883, 1884:

Imports of copper other than from Chili, at Liverpool and Swansea.

Sources.	1882.	1883.	1884.
	Tons fine.	*Tons fine.*	*Tons fine.*
From United States	745	9, 410	17, 309
Canada	347	448	266
Mexico	372	489	291
Peru	821	426	408
River Plate	260	319	131
New Quebrada	3, 164	3, 960	3, 675
Newfoundland	1, 362	1, 185	224
Spain	447	2, 659	2, 242
Portugal	17	129	117
Italy	1, 386	1, 091	1, 310
Norway	446	296	289
Cape of Good Hope	5, 298	5, 670	6, 042
Australia	112	160	446
Elsewhere	925	946	264
Precipitate	8, 757	11, 249	10, 009
Total	24, 459	38, 437	43, 023

The bulk of the Australian copper goes to London, and is not, therefore, included in the above statement, which is particularly interesting as showing how heavy were the receipts of material from the United States, the bulk being from Montana. A good deal of the latter has, however, also gone to France and Germany.

Turning now to the exports of copper and its manufactures, it is of interest to note, aside from the volume of this movement, its direction, as revealing who the principal customers of Great Britain are:

Exports of British copper (ingots, bars, and slabs) from Great Britain.

To—	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
Germany	3, 667	2, 407	4, 563	4, 976
Holland	2, 714	1, 363	2, 341	3, 300
Belgium	1, 869	2, 128	2, 307	2, 198
France	7, 172	5, 902	5, 930	3, 648
British India	1, 069	20	331	945
Other countries	2, 211	957	1, 458	2, 876
Total	18, 702	12, 777	16, 930	17, 943

The continent of Europe is the greatest consumer of unwrought copper in bricks and pigs, the bulk of the quantities enumerated under "other countries" going to Italy and Austria. In addition to this there were exported in 1883, according to special return, 11,178 tons of foreign copper, of which Germany took 3,057 tons, Holland 2,872 tons, Belgium 954 tons, France 2,180 tons, British India 1,087 tons, and Russia 530 tons.

Exports of wrought or manufactured copper from Great Britain.

To—	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
Russia	1, 315	463	540	399
Germany	702	327	318	369
Holland	509	300	232	342
France	612	1, 121	147	243
Italy	436	429	534	477
Turkey	1, 337	1, 404	1, 666	2, 608
Egypt	1, 332	560	800	1, 105
British India	4, 950	6, 570	629	617
Other countries	4, 687	4, 024	7, 203	10, 181
			3, 998	4, 328
Total	15, 880	15, 198	16, 067	20, 669

The most interesting figure in this table is that proving the heavy increase in the shipments to India, confirming the impression generally prevailing that the merchants in that country have been induced by the decline to stock heavily. How far they have anticipated future wants is not known. It is to be noted, however, that American refiners have made successful efforts in this market.

It is a curious fact, which is not widely known, that the heavy consumption of India is due largely to a religious rite of the natives. At certain seasons of the year small cups of sheet copper about an inch in diameter and an inch and a half deep are filled with rice, and are thrown into the rivers as an offering, with religious ceremonies. The quantity of copper thus annually consumed is very heavy, India sheets being an important article of commerce.

Exports of manufactures of brass from Great Britain.

To—	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
All countries	4, 657	4, 999	4, 830	5, 337

Exports of yellow metal from Great Britain.

To—	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
British India	7, 127	8, 849	10, 486	10, 494
Other countries	9, 521	9, 304	9, 268	8, 843
Total	16, 648	18, 153	19, 754	19, 337

The 1883 special return shows that 4,252 tons went to the Continent, Italy taking 920 tons, Germany 905 tons, Norway 662 tons, Holland 506 tons, France 374 tons, Belgium 228 tons, and Sweden 203 tons. Hong-Kong received 1,608 tons, Asia altogether taking 12,792 tons, while Australia bought 748 tons, and North and South America 1,832 tons, of which 781 tons came to this country.

Chili.—Little that is positive is known as to the capacity of Chili's producers to resist low prices. The two English companies working in that country, the Copiapo and the Panulcillo, do not sufficiently represent the average condition of the great number of the producers to admit of any deductions from their published annual reports. The following statement of the exports of copper from Chili will best serve to show what has been the record of this country for a long series of years:

Exports of copper from Chili.

Years.	Tons.	Years.	Tons.
1855	20, 250	1870	49, 130
1856	21, 938	1871	41, 200
1857	25, 498	1872	46, 337
1858	30, 470	1873	42, 165
1859	28, 250	1874	48, 240
1860	36, 289	1875	45 430
1861	38, 371	1876	50, 740
1862	43, 109	1877	45, 400
1863	32, 540	1878	46, 770
1864	47, 500	1879	49, 390
1865	48, 327	1880	42, 990
1866	44, 820	1881	38, 030
1867	44, 654	1882	42, 960
1868	43, 669	1883	41, 229
1869	54, 867	1884	43, 700

The principal reason why lower prices have had no effect in curtailing the output of Chili in 1884 has been that exchange has declined almost as heavily as the price of copper. When in January, 1883, Chili bars were quoted at £65 10*s.* in London, the rate of exchange in Valparaiso was 37*d.* In December, 1884, when Chili bars were sold at £47 5*s.*, exchange had fallen to 27½*d.*, thus showing a decline in the latter of 26 per cent., and in the value of copper of 28 per cent. In addition to this the export duty on bars has been repealed, amounting to about one quarter of 1 cent per pound, and other burdens have been lightened, which, together with that exemption of export duty, foot up in value to about one-half of 1 cent per pound.

Spain.—Almost the entire copper product of Spain and of Portugal is taken from the great pyrites mines of the Peninsula and is shipped in two forms—not counting a small quantity of "regulus" or matte—as precipitate and as crude pyrites which is used for the manufacture of sulphuric acid, the copper, silver, and gold being extracted from the residues. The Spanish export statistics show only the exports of "cobre en barras," presumably giving the gross weight of the precipitate, and the exports of pyrites, the copper contents of which appear in the import statistics of Great Britain and in the statistics of production of France and Germany.

Exports of precipitate and pyrites from Spain.

Years.	Precipitate.	Pyrites.
	Metric tons.	*Metric tons.*
1878	1,377	427,259
1879	20,834	459,576
1880	20,940	501,425
1881	17,710	452,475
1882	22,695	571,441
1883	24,230	564,565
1883 (eight months)	15,848	407,032
1884 (eight months)	11,162	405,673

The only explanation as yet received in relation to the falling off in shipments as revealed by the figures for the first eight months of 1883 and 1884 is that the cholera scare may have delayed exports.

An interesting estimate of the actual output of copper in the Peninsula, including the fine copper both in precipitate and pyrites, has been made by Messrs. H. R. Merton & Co., of London, who place the product as follows:

Copper production of Spain and Portugal.

Mines.	1883.	1882.	1881.	1880.	1879.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
Rio Tinto (Spain)	20,472	17,389	16,666	16,215	13,751
Tharsis (Spain)	9,800	9,000	10,203	9,151	11,324
Mason & Barry (Port.)	8,000	8,000	8,170	6,603	4,692
Sevilla (Spain)	2,026	1,885	1,340	1,705	1,360
Portugueza (Port.)	2,357	1,700	1,410	1,000	770
Poderosa (Spain)	1,000	800	800	800	800
Total	43,655	38,774	38,589	35,474	32,697

The Rio Tinto mines have more than any others excited the interest of American producers on account of their rapid development, which it is well known has not yet reached its maximum, on account of the undoubtedly enormous quantity of ore available and the low cost of production. On the latter point we possess some figures, compiled by M. E. Cumenge, an eminent French mining engineer, who made an elaborate report in the year 1883. With the old method of extraction by roasting in heaps, leaching with water, and precipitating with cast iron, he places the cost at which the ingot copper can be placed on the London market at £30 per ton, assuming that only one-half of the ore used has been taken from the open-cut workings, where it can be obtained more cheaply. The Doetsch process, it appears, effects a saving of about £4 per ton of copper. Even assuming that only 15,000 tons of copper were produced, and that that part of the business was forced to provide for the fixed charges of the company, say about £12 per ton, the miner could thrive with Chili bars below £50 in London. It is not therefore likely that there will be any decline in the output of the Rio Tinto mines.

The production of the Rio Tinto mines for a series of years has been as follows:

Production of the Rio Tinto mines.

Years.	Pyrites for shipment.	For extraction of copper by local treatment.	Total.	Actual consumption of pyrites in England, Germany, etc.	Average copper contents of ore mined.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Per cent.*
1877	251, 360	520, 391	771, 751		
1878	218, 818	652, 289	871, 107		
1879	243, 241	663, 359	906, 600	236, 849	
1880	277, 590	637, 567	915, 157	274, 201	2. 619
1881	249. 098	743, 949	993, 047	256, 827	2. 750
1882	259, 924	688, 307	948, 231	292, 826	2. 805
1883	313, 291	786, 682	1, 099, 973	288, 104	2. 956

The production of copper by local treatment at the Rio Tinto mines was as follows since 1876:

Production of metallic copper at Rio Tinto.

Years.	Tons.
1876	1, 112
1877	2, 934
1878	4, 886
1879	8, 494
1880	10, 065
1881	11, 132
1882	11, 469
1883	14, 459

In the annual report of the company for 1883 the statement is made that the works for the manufacture of copper are being laid out to reach in a few years 20,000 tons of 21 hundredweights, or 23,500 short tons.

This enormously rapid increase was not obtained without a heavy additional outlay, the growth of which the following table sets forth. The third column, "creditors," is made up of current and open accounts and bills payable. It is added merely to serve as a guide in showing why the share capital and the bonded debt were increased:

Years.	Share capital.	Mortgage bonds.	Creditors.
1879	£2, 250, 000	£2, 741, 360	£1, 507, 112
1880	2, 250, 000	4, 261, 840	473, 351
1881	3, 250, 000	2, 453, 160	256, 192
1882	3, 250, 000	2, 419, 940	751, 157
1883	3, 250, 000	2, 385, 020	993, 078

The "profit on sale of produce," the net profit, and the dividends paid were as under for a series of years:

Years.	Profit on sale of produce.	Net profit.	Dividends.
1879	£443, 930	£114, 419	£112, 500
1880	611, 340	181, 783	180, 000
1881	622, 786	*a*405, 456	395, 000
1882	698, 985	477, 184	455, 000
1883	691, 571	459, 678	455, 000

a Including £80,000 reserved from premiums on new issue of shares.

During 1882 and 1883 the dividends were at the rate of 14 per cent. on the nominal value of the shares. The usual interim dividend was £195,000, which has this year been reduced by £32,500, to £162,500. In 1879 there were outstanding £882,480 of 7 per cent. bonds, the balance of about £2,000,000 bonds being security for the floating debt. These were replaced by an issue of a more favorable character. In 1881 the share capital was increased by 100,000 shares, which produced £2,364,550, and with which the outstanding balance of the 5 per cent. Spanish coupon bonds were paid off at a cost of £1,734,600, leaving a surplus of £629,950. This did not prove sufficient to clear off the floating debt, so that the company had still to borrow £200.000 to cover the deficiency, besides what was required for working capital. Further additions to plant were made, and in 1883 it was decided, in order to consolidate the floating debt (then about £680,000), to provide a working capital, and to obtain funds to complete works, to create £1,200,000 second-mortgage bonds. The company must therefore provide for interest on over £3,500,000 bonds, and earn fair dividends on £3,250,000 share capital. Before any money can be applied for dividends on the latter a profit of about $850,000 must be made annually. On the other hand the company has developed ore reserves estimated at 100,000,000 tons, and has accumulated heaps from which copper is gradually being extracted, which are known to contain 40,000 long tons of copper, standing in the books at a cost of £6 7*s.* 6*d.*, on which the only cost is that of precipitation, estimated at £15 per ton.

The history and the present condition of the Rio Tinto Company have been dwelt upon because it is the greatest of the pyrites mines of the Peninsula, and is their best representative. The Tharsis company is the next one in importance. The amount of ore raised from the Tharsis and Calanas mines was 490,033 tons in 1883, against 486,860 tons in 1882, the shipments of pyrites being 186,366 tons of lump and 15,952 tons of smalls in 1883, against 218,218 tons in 1882. The quantity of precipitate shipped was larger in 1883, being 6,717 tons in that year, against 5,534 tons in 1882. The production of iron ore was 196,475, of which 179,811 tons were invoiced. The net profits of this enormous business were £355,689, including a balance, carried forward from the preceding year, of £21,197. Out of this, a dividend of £323,032, or 27½ per cent. on the capital of the company, was paid, carrying £10,000 to the reserve fund, and a balance of £22,648. Since operations were commenced in December, 1866, the gross profits of the concern have been, in seventeen years, £4,771,148, or, roughly, $23,150,000, which has been appropriated as follows: £3,324,354 dividends, £684,578 written off for property and plant, £471,568 for salaries, management, interest, and bad debts, £100,000 for sinking fund for railroad and docks, £10,000 for alteration of railroad, and £160,000 for reserve fund. The capital has steadily increased from £300,000 in 1868 to £785,071 in 1869, £838,797 in 1870, £900,000 in 1872, £1,136,660 in 1879, £1,143,560 in 1882, and £1,174,660 in 1883, at which figure it now stands, 37,670 shares, at £2, being still unissued and held for emergencies. The company had a debenture debt on December 31, 1883, of £279,100, of which £143,100 have since fallen due, and have been paid, leaving the amount of outstanding bonds £66,000, bearing 5 per cent., and £70,000 bearing 4 per cent. interest.

Portugal.—The principal mines in Portugal are those of the Mason & Barry Co., limited, the San Domingos, which is in many respects similar to the Rio Tinto deposit. The company which succeeded to the business of the firm of Mason & Barry has a capital of £2,100,000, of which 185,164 £10 shares have been issued. Since 1878 it has distributed among its shareholders £1,095,177 in dividends out of a total net profit of £1,289,653, having paid during the six years £60,868 interest on mortgage debentures, having written off £223,673 for property, plant, and open cost at mine, £60,000 for good will and leases, invested £23,943 in consols, placed £135,000 to the credit of rest account, from which £50,000 were transferred to profit and loss account. The product of the mine was 405,029 tons in 1882 and 382,555 tons in 1883, of which 129,437 and 123,450 tons of pyrites were shipped to sulphuric-acid makers, the company having works of its own in England. The balance of the product was worked for copper on the spot, the quantity of fine copper made not being stated, however. There are now 2,000,000 tons of ore undergoing extraction. The profit for 1883 was only £195,993, as compared with £276,719 during the preceding year, and

£50,000 were transferred from the reserve account to make up the usual dividend of 12½ per cent. per annum.

Germany.—Further progress has been made during the year 1883 in the output of the production of copper in Germany. Official statistics are now gathered for the entire empire and these have been adopted for the years 1882 and 1883. It is presumed, however, that they do not include the product of the Hamburg electrolytic works.

Production of copper in Prussia and in the Mansfeld district.

Years.	Prussia.	Mansfeld district.
	Metric tons.	*Metric tons.*
1875	7,212	6,283
1876	8,235	6,908
1877	8,661	7,971
1878	9,096	8,546
1879	10,165	9,813
1880	14,593	10,999
1881	15,702	11,000
1882	*a*16,653	11,691
1883	*a*18,194	12,836

a German Empire, assuming matte produced to carry 50 per cent. of copper.

The product of the Mansfeld district, practically the yield of one very large corporation, has been specially given because, outside of the Rammelsberg mine, it is the only concern working an important deposit. The balance of the copper product of the empire is obtained partially from the extraction of the metal from the residues of roasted imported iron pyrites and from a scattered quantity of ore obtained as a by-product in mining for lead and zinc. A considerable quantity of Spanish and Portuguese precipitate is refined by one large copper-rolling establishment.

The Mansfelder Kupferbauende Gewerkschaft, one of the great copper producers of the world, hoisted from its narrow bed of cupriferous shale 536,086 tons of ore, and made from it 36,687 metric tons of matte, which in roasting yielded a by-product of 17,487 tons of sulphuric acid. It turned out 12,836 metric tons of fine copper, and 64,463 kilograms of silver, and made a profit of 3,091,699 marks in the year 1883. Referring the entire profit to the copper alone, this sum represents a profit of 3.2 cents per pound of ingot copper, or £15¾ per long ton, so that the decline of the year 1884 does not reduce the earnings below its expenditures. The company is managed with the closest economy, and with a constant watchfulness so far as the technical details of mining and metallurgy are concerned; and it is not too much to say that without the exercise of these precautions the mines would have been abandoned years since, as the bituminous shale hoisted does not average more than 2.85 per cent. of copper, and 0.015 per cent., or 4.37 ounces, of silver per ton.

The export movement from Germany may be traced from the following general table:

Exports of copper and copper manufactures from Germany.

Character.	1879.	1880.	1881.	1882.	1883.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*
Ingot copper and brass	9, 387	7, 204	7, 704	6, 097	5, 751
Copper rods, sheet, and wire	3, 200	3, 928	5, 130	1, 997	2, 058
Manufactured copper	2, 972	4, 195	4, 737	3, 854	3, 868
Total	15, 559	15, 327	17, 571	11, 948	11, 677

Official statistics, kindly prepared specially at the request of the United States Geological Survey by the imperial German Bureau of Statistics, give the destination of the exports of copper as follows:

Destination of exports of copper from Germany.

Destination.	Ingot copper.		Sheet and rods.		Wire and telegraph cable.	
	1882.	1883.	1882.	1883.	1882.	1883.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*
Bremen			62	30		8
Hamburg	373	126	174	263	34	38
Russia	325	142	154	297	40	47
Austria	3, 788	4, 492	93	127	47	136
France	349	119	26		24	17
Belgium	784	422	136	18	9	10
Netherlands	190	138	356	123	100	109
Great Britain		96		45	68	63
Italy		79	138	138	35	58
Other countries	286	137	270	339	251	193
Total	6, 095	5, 751	1, 409	1, 380	608	679

In addition to these exports Germany shipped to other countries in 1882 1,066 tons, and in 1883 955 metric tons of "coarse" copper and brass forgings and tubes, 203 and 187 tons, respectively, of copper-nickel and brass wire cloth, and 2,584 and 2,725 tons, respectively, of light copper and brass forgings. In the aggregate its exports of ingot copper and manufactures of copper and brass were 11,948 tons in 1882 and 11,677 tons in 1883.

The difficulty usually encountered in tracing the import and export movement of Germany, growing out of the fact that Hamburg is a free port, is enhanced in the case of copper, because there is a local reduction works, the product of which is not known, and which is not returned in any statistics. Treating ores and furnace material by the electrolytic process, it might be believed that the special returns of argentiferous and auriferous material might furnish a clue, but unfortunately Hamburg is the port of entry of the foreign material treated at the Mansfeld works. In 1883 812 tons of argentiferous ore and 575 tons of argentiferous copper were imported. A part of the latter may have gone to bluestone works. From a statement of the quantity of copper deposited daily by the electrolytic process at the Hamburg works, it is estimated that its output is 750 metric tons per annum.

Still the exports via Hamburg and Bremen are comparatively light, as the table given proves, and the general result is not much affected. It proves that Austria receives the bulk of the exports from Germany so far as ingot is concerned. To what extent this is merely material in transit it is difficult to ascertain so far as the raw material is concerned. Germany is a considerably heavier importer than exporter, while on the other hand it exports more manufactured copper than it receives from other quarters. As is usually the case, its exports of the more finished products are much more widely scattered, going in small quantities to many different countries. The following table gives the imports of copper and copper manufactures into Germany. During the present year the United States have contributed a larger share, numerous sample lots of ingot copper and of copper matte having gone to Germany, which also receives considerable Lake copper, directly and indirectly, from England and France. The exact figures for the direct shipments are not available, while those indirectly made cannot be traced.

Imports of copper and copper manufactures into Germany.

Character.	1879.	1880.	1881.	1882.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
Ingot copper and brass	13,378	12,719	11,372	10,579
Copper rods, sheet and wire	608	770	437	230
Manufactured copper	1,201	1,015	1,119	1,015
Total	15,187	14,504	12,928	11,824

Cape of Good Hope.—Regular contributors to the world's markets for many years past have been the mines of the Cape Copper Company, limited, an English corporation which has been exceptionally successful. The principal producer at the present time is the Ookiep mine, which in 1882–'83 yielded 15,827 tons of 28.6 per cent. ore and in 1883–'84 15,588 tons of 29.23 per cent. ore, while 1,728 tons of 37.56 per cent. ore in the former year, and 1,800 tons of 39.16 per cent. ore in the latter year were raised from the Specktakel mine; the Springbok, the early wonder of the district, being now practically exhausted.

The company has its own smelting works in England, and turns out annually from 5,000 to 5,300 long tons of fine copper. The net profits in the fiscal year 1882–'83 were £145,465, and in the last year £101,135, the cost of production varying little from £207,000 annually, or 8*s*. per unit, equivalent to £40 in Chili bars. So long as the reserves of high-grade ore last the company will remain a steady producer of metal. The yield in 1884 is estimated at 6,699 tons of fine copper.

As one of the phases of the new German colonial policy, attention of German adventurers has been directed to the copper resources of Angra Pequeña, and exploration is now going on in a vigorous manner.

Australia.—The principal increase in the output of the Australian colonies has come from New South Wales, South Australia barely holding its own, as the following figures, compiled from various sources, show:

Exports of copper and furnace products from the Australian colonies.

Years.	South Australia.		New South Wales.		Queensland.
	Ingots.	Ores.	Ingots.	Ore and regulus.	Ingots.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1870	5, 471	20, 886	994	6	1, 523
1871	6, 396	20, 127	1, 350	94	2, 490
1872	7, 452	26, 964	1, 035	417	2, 448
1873	7, 087	27, 382	2, 795	51	(?)
1874	6, 629	22, 854	3, 638	522	(?)
1875	6, 842	26, 436	3, 520	157	(?)
1876	5, 463	22, 682	3, 106	169	2, 105
1877	5, 143	18, 532	4, 153	360	544
1878	3, 594	17, 007	4, 983	236	642
1879	(?)	(?)	4, 107	36	....
1880	(?)	(?)	5, 262	132	....
1881	(?)	(?)	5, 361	133	....
1882	3, 647	25, 897	4, 865	93	....
1883	2, 442	*a* 3, 756	8, 873	84	*a* 98

a Receipts in England in 1883.

The principal mine in New South Wales, and one which has been exploited for a long time, is the Great Cobar, which in 1883 made 2,401 tons of fine copper from 18,096 tons of ore. The mine inspectors report that it has very large reserves. The Nymagee Company produced 1,714 long tons of fine copper from 10,236 tons of ore, and the Burraga 520 tons from 6,150 tons of ore. How far these mines will be able to outlive low prices, with the limited transportation facilities now at their service, and the frequent troubles from drought, cannot be stated, since no reports concerning their financial affairs are available. It is certain, however, that the growing activity in prospecting in the colony will be checked.

In South Australia the business report of the English and Australian Copper Company, owners of the Burra Burra mines, clearly reflects the distress caused by low prices. For the fiscal year ending June 30, 1883, the two smelting works of the company, at Port Adelaide and at Newcastle, received only 7,683 tons of matte, against 10,715 tons during the previous year, the falling off being, however, largely due to drought. On a product of about 3,452,000 pounds of ingot, the company made only a profit of £1,435.

France.—The following is a statement of the quantity of copper produced in French works, chiefly from imported ores and furnace material:

Production of copper in France.

Years.	Metric tons.	Years.	Metric tons.
1870	2, 100	1877	2, 330
1871	2, 720	1878	3, 500
1872	2, 600	1879	3, 350
1873	2, 140	1880	3, 300
1874	2, 000	1881	3, 395
1875	2, 300	1882	3, 627
1876	2, 230		

France is a very small copper producer, but in 1883 handled an unusual amount of foreign ore, comparatively speaking, large shipments of arsenical medium-grade material having been made to the Septemes works, where the Manhès copper matte Bessemerizing process was applied to it, with, it is claimed, great success. This ore was shipped from Butte, via San Francisco, around Cape Horn.

While unimportant as a producer of copper, France is a very heavy consumer, and is particularly interesting from that point of view to the Lake producers, taking as it does the bulk of the Lake copper exported. According to statistics published in England, the receipts of American copper in 1884 were 7,260 long tons; of Chili bars, ingots, and barilla, 11,086 long tons, and of copper from sundry sources 337 tons, thus indicating total imports of 18,683 tons. One of the principal French copper manufacturing industries is art casting, in which the value of the raw material used bears a comparatively insignificant proportion to the value of the finished product. To insure a faultless casting the very best quality of copper is sought, and Lake has obtained a firm foothold in that market.

The following figures, compiled by English authorities, show the magnitude of the French copper trade:

The French copper trade.

Years.	Imports, all kinds direct.	Imports of American, etc.	Imports of Chili.
	Long tons.	*Long tons.*	*Long tons.*
1876	16, 418	4, 220	12, 198
1877	13, 015	4, 030	8, 985
1878	13, 094	4, 016	9, 078
1879	10, 402	4, 675	5, 727
1880	11, 818	320	11, 498
1881	16, 436	3, 205	13, 231
1882	13, 573	1, 379	12, 194
1883	20, 894	4, 830	16, 064
1884	18, 683	7, 597	11, 086

Austria.—From official data kindly furnished by C. von Ernst we have compiled the following statement of the production of copper in Austria since 1879:

Production of copper in Austria.

Years.	Metric tons.
1879	259
1880	500
1881	482
1882	482
1883	581

Over one-half of this product or 323 tons is produced at the Mitterberger Hütte, Salzburg. At Witkowitz, Moravia, 112 tons of precipitate was made from 149,538 tons of roasted pyrites, partly imported, the product being sent out of the country to be refined. The balance was made at two works in Tyrol, one of them, the Brixlegg works, belonging to the Government.

The native copper industry is therefore very unimportant, and Austria must rely largely for its supplies of the metal upon foreign countries. In 1883 the imports were 6,646 metric tons of copper, of which 6,260 tons came from Germany, and only 295 tons by way of Trieste. The exports were 515 tons, of which 338 tons went to Germany. The apparent home consumption was therefore 6,712 tons in 1883.

Hungary.—The latest official statistics available cover the year 1882. The production in that year was 672 metric tons, as against 1,036 metric tons in 1879.

Canada.—The miners of the Capelton district have continued to furnish to American sulphuric-acid makers a very large share of the pyrites used by them, and the cinders, smelted partly at the chemical works and partly at the Orford refinery, have been converted into matte from which the bulk of the copper reported under that head has been extracted. The shipments to England have dwindled to insignificant figures, the receipts at Liverpool and Swansea being estimated to contain 266 long tons fine in 1884, against 448 tons in 1883 and 347 tons in 1882.

The efforts to establish a large copper industry on the north shore of Lake Superior on deposits similar to those of the Peninsula have failed signally, although heavy amounts were invested in exploration and plant by English capitalists.

Newfoundland.—The Tilt Cove, Bett's Cove, and Little Bay mines have evidently, if the falling off in the shipments to Great Britain are a criterion of their status, seriously felt the effect of the decline in values. In 1884 the receipts in Liverpool and Swansea were only 224 long tons fine, as compared with 1,185 long tons in 1883 and 1,362 tons in 1882. It should be stated, however, that a large shipment of 1,000 tons of 4 to 5 per cent. ore was made to this country in 1884.

Mexico.—American capitalists have become interested in a number of copper mines, particularly in the northern part of the country, and a number of plants have been put up without as yet producing notable quantities of metal. Some of the copper has come to American refining works, but the bulk of the ores and furnace products go to Great Britain, where the receipts were 291 long tons in 1884 compared with 489 long tons in 1883 and 372 long tons in 1882. Reports from reliable sources, however, indicate that deposits of exceptional magnitude exist in Lower California, near Cape Saint Lucas, accessible by sea, so that smelting works commanding a comparatively cheap supply of English coke would be enabled by working the high grade ores to become formidable contributors to the world's supply. It has been stated that the control of this property has passed from the hands of a Guaymas firm to a syndicate of French capitalists.

Venezuela.—For some years upward of 3,000 tons of copper annually have been marketed by the Quebrada Railway, Land, and Copper Company, an English company, a consolidation of formerly independent railroad and mining companies. It works a pyrites deposit, shipping the higher grade of ores and smelting the lower grade to matte for export. The applicability of the Rio Tinto wet methods to the treatment of the poorer ores has been investigated, but as yet the results have not been published. In 1882 the sales amounted to 3,415 long tons, increased in 1883 to 3,589 long tons. The latter product, in spite of the higher prices prevailing in 1883, failed to yield a profit, and the Quebrada mines may be placed among those which will be unable to compete at current figures. The receipts from Venezuela in 1884, however, showed no material decline, being placed at 3,675 long tons.

THE MINES AND REDUCTION WORKS OF BUTTE CITY, MONTANA.

By E. D. Peters, Jr.

THE MINES.

The high position that Butte City, Montana, now occupies as a producer of the valuable metals, standing second only to Lake Superior in its shipments of copper, and ranking among the first in its production of silver, has naturally attracted much attention among those interested in mines and metals. Several valuable articles have appeared in certain technical journals descriptive of some of the individual mines of this district, but I have yet to learn of the publication of any general descriptive paper, giving an idea of the geology of the camp, the peculiarities of its veins, and a trustworthy description of the methods employed for the treatment of its ores. The object of the present paper is to partially fill this gap; and if it is noticed that less attention is paid to the three or four great silver mines and mills that first gave Butte its celebrity than their importance would seem to warrant, it is because exactly this subject, to the exclusion of nearly all other interests, has received particular attention in the articles already mentioned, and because full accounts of the Alice, Lexington, and Moulton mines and mills are accessible to all.

The district.—That portion of the Butte camp which to the present time alone possesses especial interest to the miner may be mostly inclosed within the lines of a rectangle having a length of 2½ miles and a breadth of 1 mile, roughly speaking. This rectangle extends from Yankee Doodle gulch on the east to a point somewhat below the Boston and Colorado Concentrator on the west, and from the northern extremity of Walkerville district on the north to the extension of Park street on the south. Within these narrow limits are the three great silver mines already mentioned, the Anaconda, Parrot, Colusa, Bell, Liquidator, Gagnon, Saint Lawrence, Mountain View, Clear Grit, and dozens of other noted and productive mines, besides the whole system of silver-bearing manganese leads, and an almost indefinite number of veins already discovered, and more or less developed. Outside this small area, though there is no lack of prospects, some of which promise exceedingly well, I do not know of a single property which can yet (autumn of 1884) be classed among the paying mines.

Geological.—The geology of this rich metalliferous rectangle is at first glance exceedingly simple, consisting apparently solely of a coarse-grained and very hard granite, containing an undue proportion of quartz and mica, and less feldspar than is usual. On closer inspection it will be noticed that while in the eastern or cupriferous portion of the area mentioned the granite is exceedingly coarse grained and shows no sign of stratification, in the western or argentiferous division the mica predominates, and is arranged to a greater or less extent in parallel layers, approaching a mica schist. So far as my observations extend, the feldspar is entirely orthoclase, while both the brown and white varieties of mica (biotite and muscovite) occur, though in widely varying proportions at different points. There is a regular and well-marked connection between the structure of the granite and the contents of the fissures by which it is traversed; but neither the scope of this paper nor the observations at my disposal warrant any further speculation in this direction.

The miners universally speak of porphyry dikes, which run parallel with, and usually form the walls of, all the large copper veins that have been opened to any great depth. But in every instance where I have been able to examine the matter personally the so-called "porphyry dike" has been found to be merely an altered granite, in which the solutions flowing through the vein and saturating its walls to a considerable distance on either side have apparently decomposed the feldspar and frequently the mica, leaving the fragments of quartz which once helped to form the granite surrounded by, and embedded in, the silicate of alumina which now represents the feldspar, and altogether yielding a belt of rock parallel to the vein and bearing a remarkable resemblance to porphyry. In other cases the results of decomposition have been such that the altered granite resembles a fireclay containing angular fragments of quartz. This is often used where refractory material is required, and though not equal to a good fireclay will still stand a very high temperature without melting. Of two bricks made from this decomposed granite, one (the smaller) was placed in a white-hot muffle for several hours, while the larger one was used as a support under the end of the same muffle for several weeks—a severe test even for a good firebrick—and both were removed practically unaltered.

But on the bridge wall of a reverberatory smelting furnace a few hours sufficed to melt it into a pasty mass, while a Golden City firebrick showed only a slight rounding of the thinnest edges. I have given these details, hoping that they may undeceive certain inhabitants of Butte who are holding these leads of decomposed granite under the mistaken impression that they possess a great future value.

Classification of the veins.—As even an imperfect attempt at classification is preferable to complete chaos, the Butte veins may be divided, for convenience of description, into two great classes:

1. Copper veins, carrying more or less silver.
2. Silver veins, carrying little or no copper, and having a manganese gangue.

One or two of the most noted Butte mines, the Gagnon and its extensions, cannot be classed under either of these divisions, and must be described separately.

The first group embraces the Anaconda, Parrot, Liquidator, Bell, etc. The second group includes the Alice, Lexington, Moulton, and many others of less note, but exhibiting the same surface characteristics. While both the valuable minerals and gangue of these two systems of veins are quite different, and while each group is geographically tolerably distinct from the other, they still possess many features in common. For instance, they all traverse a granite formation; they are nearly all accompanied by the zones of decomposed country rock described above; they nearly all pitch either perpendicularly or at a very steep angle; though they are doubtless true fissure veins, they lack entirely, so far as my observation extends, that distinct demarkation between vein and country which is in some districts so very striking; nor do any of them possess the clay gouge on either foot or hanging wall, which is sometimes of such an assistance to the miner when drifting on the course of the vein. They all, without exception, contain copper and silver, though in widely varying proportions, and most of them contain traces of gold.

The copper veins.—These usually appear on the surface as wide bands of quartzose rock, much decomposed and heavily stained with oxides of iron. Carbonates and oxides of copper mostly appear only as stains, so that, as will be seen, there is little indication of the immense value below. This surface ore invariably carries silver, generally in a free-milling condition, and in most of the larger veins in sufficient quantities to pay for treatment. In fact, nearly all the mines that are now considered distinctly as copper leads, such as the Anaconda, Parrot, etc., were first treated exclusively as silver properties—assaying from 10 to 60 ounces per ton, and averaging perhaps 20 ounces. This surface ore continues until the water line is reached, at a depth of from 50 to 150 feet, when, without warning, it changes at once into the base ores that now constitute the principal value of these leads. These ores are somewhat indefinite minerals, resembling copper glance, erubescite, peacock copper, and some irregular compounds of copper, iron, and sulphur. Neither the Butte copper glance nor erubescite agrees exactly, either in its physical or chemical characteristics, with the mineralogical description of these compounds, and a careful study of them would amply repay any skilled mineralogist. A small quantity of copper pyrites is also found, but though most of the copper ores are slightly arsenical, I have as yet seen nothing resembling fahlerz (gray copper ore). I agree with Mr. William Semmons in considering enargite to be the principal source of arsenic.

The condition in which the silver occurs in the free-milling ore is yet undetermined. The miners speak confidently of large amounts of chlorides, bromides, "carbonates," and even "oxides" of silver, and it is certainly the prevailing impression that most of the precious metal occurs in these rare compounds; but aside from small quantities of chloride of silver, I have been unable, either by chemical or physical examination, to detect any of the salts of silver referred to, nor have I found any local chemist who has been more successful. Below the water line the silver is principally contained in the erubescite and copper glance, very small assays being obtained from either pyrite or chalcopyrite. But I am also inclined to think that it occurs largely as a thin coating of sulphide on the cleavage planes of the peacock ore; as frequently, on breaking open such ore masses, the whole plane is found plated with a thin coating of native silver, which has evidently resulted from the reduction of argentic sulphide.

Perhaps the next most noticeable feature of the Butte copper veins is their great size and remarkable continuity. It is not at all uncommon to find the vein 30 feet in width for several hundred feet of its course, and filled with ore from wall to wall for its entire distance. I am now referring to second-class ore, suitable for concentrating, and assaying from 5 to 18 per cent. of copper. This grade of ore forms the princicipal value of the camp, occurring with such regularity and in such large bodies that mining is robbed of most of its risks. The first-class ore is distributed with little regard for regularity, in chutes, chimneys, pockets, kidneys, and every other conceivable form, and on an average may constitute one-tenth of the entire ore. Where the various mines differ so greatly in both strength and quality, it is difficult to give average figures with any approach to accuracy, but I think I am well within bounds in placing the average width of pay ore in the principal copper veins at 7 feet. The Anaconda is the widest of any yet opened, averaging certainly over 12 feet of profitable ore, and in many places widening to 30 and 40 feet for a great distance. In order to show the unusual depth which this erubescite ore attains in this district, before being replaced by the poorer yellow sulphides which doubtless form the normal unaltered ore of these veins, I will mention here that the 800-foot level of the Anaconda shows no diminution in the richness of the ore. (If I remember rightly, the deepest point in Chili at which these peacock ores have held was in the celebrated Piqué mine at a depth of about 500 feet, at which point the rich erubescite ores were replaced by yellow sulphides, averaging about 7 per cent. It seems probable that Butte may count on a still greater depth of rich ores.) The Parrot and Liquidator also carry exceedingly strong ore bodies, and of remarkable continuity.

For convenience of more minute description, the copper veins may be classed in two subdivisions:

1. Those in which the copper is found mainly in the shape of copper glance, or a mineral greatly resembling copper glance, though not containing quite the amount of copper called for by the formula CuS.

2. Those veins in which erubescite is the principal copper-bearing mineral.

The Anaconda and Liquidator are good examples of the first division, having, as a rule, a gangue rock of quartz and decomposed feldspar, and carrying scarcely any other ore, except copper glance and a small percentage of pyrite, thus yielding concentrates of a very high grade; while the first-class ore, which is now sacked and shipped to Europe, consists entirely of high grade, forming, both as regards quality and quantity, perhaps the finest shipping product in the country. The Liquidator and Colusa also furnish a very large amount of second-class ore, which is sufficiently free from pyrite to concentrate to 30 per cent. and over, though in the lower levels, as might be expected, the proportion of pyrite has decidedly increased.

The second division is represented in its most perfect type by the great Parrot vein and its eastern extension, and for some 2,000 feet carries an almost uninterrupted ore chute so far as explored. It is characterized by its high percentage of erubescite, carrying nearly its entire copper contents in the shape of that mineral, the occurrence of copper pyrites being rare and unimportant. The first-class ore can be easily selected to 30 per cent., while nearly the entire vein, from 5 to 30 feet in width, is suitable for concentration, sampling 12 per cent. as the average of three years' working. But it is not alone as a copper vein that the value of the Parrot must be estimated; it is also a silver-bearing lead of great value, carrying on an average two-thirds of an ounce of silver to each per cent. of copper, while above the water line, to a depth of 80 feet or more, there is a fine body of free-milling silver ore of great strength and value left untouched.

The value of nearly all these veins is considerably enhanced by the fact that to a depth of 800 feet no serious amount of water has been encountered, and that where proper appliances have been introduced, natural ventilation suffices to keep the air in a perfectly good condition. The country rock is also of such a quality that no difficulties are encountered in timbering, beyond such as naturally arise in working out an ore body of 30 to 40 feet in width, and which supplies no barren material for filling.

The silver veins.—The second great division of veins includes the manganese-silver group, and presents certain unique features. In speaking of the formation and mineralogical characteristics of these leads, I am fortified by the opinion of Prof. Alvin Weisbach, professor of mineralogy at the Freiberg School of Mines, who examined some of the mines and ores of this district with me. These manganese veins all lie in a small and strictly circumscribed territory, to the west and north of the copper group, and most of them crop boldly to the surface, forming often large comb-like ridges of brown and black rock, stained principally by the oxides of iron and manganese, and showing every evidence of thorough decomposition. On closer examination, these croppings are found to consist of a more or less prominent quartz skeleton, heavily charged with the minerals of manganese known as pyrolusite, psilomelane, braunite, and wad. They occur in the order mentioned as regards frequency of appearance, the latter being comparatively rare. They are almost exclusively in a massive or amorphous condition; crystals, or even evidences of crystallization, being almost unknown. But as interesting as the occurrence of these extensive masses of oxide of manganese in a district otherwise filled with sulphides may be to the geologist, they are still more interesting to the miner, from the fact that they are, without exception, argentiferous, though varying from 3 or 4 to several hundred ounces per ton. The average value of the selected ore extracted from these leads may be about 20 ounces, but in what chemical condition the silver occurs I am unable to say positively, though I can state with certainty that it does not occur either as a bromide or iodide, as seems to be the popular opinion, nor in my own investigations have I been able to satisfy myself of the occurrence of chloride, except in traces.

The percentage of manganese varies as greatly as does the silver value, and unfortunately stands in an inverse ratio to it; the massive ores of manganese seldom containing more than a few ounces of silver, while the ores rich in silver have, as a rule, a gangue of quartz rather than of manganese. This is a serious drawback in smelting, for as quartz predominates in nearly all the Butte ores, an addition of manganese would be a most welcome flux. A few analyses of these ores will illustrate the above statements.

A sample of surface ore from the Nile mine, which represents fairly the better class of manganese ores, was found to contain:

Analysis of manganese-silver ore—No. 1.

	Per cent.
Oxides of manganese	47.60
Oxides of iron	12.40
Silica	34.20
Alumina	3.70
Silver (32 ounces)	.11
Sulphur	Trace.
Moisture and loss	1.99
	100.00

A massive piece of manganese ore (a mixture of braunite and psilomelane) from unknown mine contained:

Analysis of manganese-silver ore—No. 2.

	Per cent.
Oxides of manganese	88.40
Oxides of iron	3.20
Silica	6.60
Silver (9 ounces)	.03
Moisture and loss	1.77
	100.00

A mill sample of a 20-ton lot of ore from a noted manganese mine near Butte, stoped at a depth of about 40 feet from the surface, contained:

Analysis of manganese-silver ore—No. 3.

	Per cent.
Oxides of manganese	21.000
Oxides of iron	7.700
Silica	66.400
Alumina	2.400
Silver (80 ounces)	.275
Moisture and loss	2.225
	100.000

These analyses have been selected as types of the principal varieties of manganese ores, and show plainly the decrease of manganese as the silver contents increase.

In describing the first division, or copper leads, of this district, I have shown how suddenly the vein contents change at the water line, from an almost free-milling silver ore without any copper to a massive sulphureted base-metal ore, rich in copper and generally poor in silver. The transition is at least equally striking in the second or manganese-silver division. Here again the water line constitutes the boundary, and the decomposed masses of brown, yellow, and black oxides of iron and manganese change almost instantaneously into a gangue of silicate and carbonate of manganese (the former greatly predominating), with a large admixture of quartz, the whole being specked and threaded with minute granules and veinlets of zincblende, pyrite, chalcopyrite, and galena—the two latter materials occurring in very subordinate quantities, and the entire amount of sulphureted minerals seldom exceeding 5 per cent. of the ore, and much more frequently falling below 3 per cent., though in the Lexington and Alice mines bodies of very base ore are encountered.

The silicate and carbonate of manganese have their characteristic pink color, and contrast very beautifully with the white quartz, but although the ore usually retains its full silver value, as compared with the upper decomposed portion of the vein, it has lost its worth as a flux in smelting, and, as a rule, is only fit for milling. I am at a loss to say in what condition the silver occurs in this ore. Owing to the high assays that I have often obtained from specimens which showed only the most minute specks of sulphide minerals, I have been led to search most carefully for some of the noble silver minerals, such as silver glance, brittle silver, etc., but entirely without success; nor could the experienced eye of Professor Weisbach detect any trace of them in the various specimens submitted to him. Chemical tests also disprove the existence of silver chloride, so that as yet I am unable to explain the matter. The popular opinion is that the silver is contained in the zincblende and pyrite, but when the entire weight of those minerals forms less than 2 per cent. of a given sample that assays 1.5 per cent. in silver, it is difficult to reconcile that theory with the facts of the case. This is a very interesting and important subject for future research.

Although not generally so considered, the great mines that have given Butte its celebrity as a silver district, namely the Lexington, Alice, Moulton, etc., belong strictly to this manganese-silver group, though their water line being comparatively near the surface, the oxidized zone continues but to a slight depth. They still show plenty of "pink manganese," as the carbonate and silicate of manganese are indefinitely termed by the miners, but on the whole quartz predominates decidedly and zincblende and pyrite occur in much larger proportion than in most other mines of this group. I need hardly say that this necessitates a thorough chloridizing roasting prior to amalgamation, and in fact none of the manganese ores that occur below the water line can be treated raw with any satisfactory results.

At present, with the exception of the great mines already mentioned, the manganese-silver belt is adding but little to the production of Butte. A few hundred tons per month of heavy manganese ore, assaying from 15 to 50 ounces of silver, are mined and sold to the Boston and Colorado Smelting Works, and a much smaller quantity of more quartzose ores are treated in custom mills.

Few, if any, of these mines—always with the exceptions above mentioned—are worked below the water line, and they are mostly too quartzose and too poor in silver to pay for smelting, nor can many of them stand the losses and heavy milling charges incidental to amalgamation. In time, with cheaper fuel and labor, I think a small proportion of them may prove of some value, but not before they come into the hands of companies willing and able to erect mills on a very large scale and look to small profits per ton on large amounts of ore for their reward. At present most of them are in the hands of poor men who can do nothing with them themselves, but who hold them at prices that are virtually prohibitory to capitalists.

The Gagnon.—In my attempted classification of the Butte mines I have encountered one difficulty in the shape of the Gagnon mine, which is so different from either class described as to be positively unique, and it demands at least a few words to itself. As regards geographical position, it is assumed, and I think correctly, to be the western extension of the great Parrot lode, and apparently while trying to hold its own as a copper lode it has (together with its extensions, the Original and the Butte Original) been so powerfully influenced by the conditions which governed the formation and filling of the silver group into which it extends that it has assumed a mixed character, intermediate between the two divisions, and yet possessing certain characteristics of its own. While its percentage of copper is much lower than that of any of the true copper veins, its contents in silver are for the most part higher than any but the very richest of the silver group. Its gangue is principally quartz, and its chief ore an argentiferous zincblende, though the compounds of copper which occur in the Gagnon also carry a considerable quantity of silver, as does the iron pyrites, which occurs abundantly.

The ore occurs in very large and strong pay chutes, and, so far as exploration has yet gone, certainly does not improve in depth. The best ore, both in quantity and quality, was found near the surface, several hundred feet above the present workings, but I am credibly informed that it is now rapidly improving in the deeper levels, and that every indication is present of other large bodies of rich ore in near proximity.

The Butte minerals.—A list of minerals from this mining district, determined by myself, is appended. Those marked with exclamation points (!!) are rare in this place.

Graphite!, native gold, native silver, argentite, cerargyrite, chalcocite, chalcopyrite, erubescite, cuprite, malachite, azurite, chrysocolla, galenite, anglesite, cerussite, sphalerite, rutile, molybdenite, pyrite, pyrrhotite, enargite, tetrahedrite, arsenopyrite!, pyromorphite!, hematite, magnetite, limonite, siderite, pyrolusite, psilomelane, braunite, wad, manganite, rhodonite, rhodochrosite, calcite, barite, witherite!, quartz, jasper, pyroxene, tremolite, actinolite!, hornblende, garnet, epidote, biotite, muscovite, andalusite, orthoclase, oligoclase, cyanite.

THE REDUCTION WORKS.

Methods of treatment.—The foregoing classification of the Butte mines may be partially adapted to the metallurgical process employed for the reduction of the ores. But as differing conditions may suggest different methods for the treatment of the same ore, I find it convenient to to divide the processes here in operation into five classes:

1. Raw amalgamation of silver ores.
2. Chloridizing-roasting and amalgamation of silver ores.
3. Smelting of silver ores in reverberatory furnaces, with the addition of sufficient copper ore to form a highly argentiferous matte.
4. Smelting of copper ores in reverberatory furnaces.
5. Smelting of copper ores in blast furnaces.

It will be noticed that the classes numbered 3 and 4 are nearly identical metallurgically, as in both cases the product is a copper matte, in which whatever silver happens to be in the ore is concentrated, the quantity of the precious metal being in any case so small as to have no effect on the method employed, metallurgically speaking, however important it may be from a commercial standpoint. But the quality of ore treated is so different in the two cases referred to, and the employment of oxide of manganese almost exclusively as a flux for silica in No. 3 is so interesting and so rare, as to demand a separate notice.

In Nos. 3, 4, and 5 a certain proportion of the ore is prepared mechanically for the furnace by wet concentration, and as this is the step that naturally follows mining, its description is in place here.

Concentration.—There are four separate concentration works in Butte, having an aggregate capacity of about 300 tons of raw ore daily, and at least three more already about completed or in progress of erection, which are estimated to treat an additional 350 tons per day. These, of course, are exclusive of the great works at Anaconda, which are expected to concentrate 500 tons daily, and with sufficient furnace capacity to smelt the concentrates produced.

In describing both smelters and concentrators I shall naturally make most use of such facts as are personally familiar to me as the metallurgist of what may perhaps be considered the representative copper works of the district. I trust this may be considered a sufficient excuse for any statements that may not apply strictly to all the establishments in the class referred to.

Our ores of copper being mostly erubescite and copper glance, have a sufficient specific gravity (5), as compared with their quartz gangue (2.5), to permit of a tolerably perfect separation, but the unfortunate tendency of these high grade copper minerals to form slimes, combined with their very high percentage in copper, necessitates a heavy loss in concentration, especially in the fine tailings, and one that can be only partially remedied by extensive slime pits, as the fine copper dust once brought in contact with water settles with extreme difficulty, and long remains floating on the surface of even stagnant water.

Another serious drawback in most of the mines is the occurrence of pyrite, so intimately mixed with the ore as to defy handpicking. Having nearly the same specific gravity as the copper ore, and a less tendency to form slimes, it concentrates even more perfectly than the valuable constituents, and positively prevents the production of a concentrate containing over from 20 to 30 per cent. of copper, except in the case of the Anaconda and one or two equally fortunate mines, where the proportion of pyrite is so small as to permit of a product carrying from 45 to 50 per cent.

I have made a series of careful experiments, with a view to the discovery of some means by which the iron and copper minerals might be mechanically separated. Finding that a slight discrepancy in specific gravity exists between erubescite and pyrite, I hoped to obtain, at least on the first sieve of the jig, a product high in copper; but discovered, after repeated trials, that there was just about enough difference in the form of the grains of each mineral, owing to their different cleavage planes (the heavier mineral consisting mostly of long, flat grains, while the lighter breaks rather into solid cubes), to effectually neutralize any advantage that their difference in gravity might offer. Failing in this trial the next most promising idea seemed to lie in the fact that the thorough calcination of iron pyrites, as practiced with us, yields principally a highly magnetic oxide of iron, which quality I hoped to take advantage of to separate it from the oxide of copper. But on trial I found that erubescite (a compound of iron, copper, and sulphur) also yields after calcination a highly magnetic powder, and that the result of passing a magnet through our calcined concentrates was to remove everything except what small percentage of silica was present. Whether this plan might prove more successful on a mixture of pyrites and copper glance—which latter mineral does not become magnetic on roasting—I have not had the opportunity of determining.

While the concentration works now in operation in Butte, as well as those in process of erection, are by no means model establishments, they still do very good average work, and are perhaps quite as well adapted to the peculiar conditions as more elaborate works. The loss of copper in the tailings is considerable, and under eastern conditions could not be tolerated; but it must be considered that in Butte the ore is the cheapest thing we have, while fuel, labor, and machinery are extremely expensive, and that the copper contained in the ore has cost so little to mine that it does not acquire any considerable value until a certain amount of labor has been expended on it.

While I do not deny that a more perfect sizing, a graded system of crushing, and a more systematic effort to concentrate the finer classes of ore might even now prove remunerative, I doubt very much if it would pay expenses to greatly extend the present system of slime treatment, in which department the principal losses occur. I can, however, assert positively that at least one of the concentrating mills in course of erection is so arranged as to carry out to a considerable extent the improvements just discussed.

The general system of working is to crush the ore first through a coarse and then a finer rock breaker, a $\frac{3}{4}$-inch mesh screen being interposed between the two breakers to remove such ore as is already sufficiently fine for the first set of rolls, to which all the ore from the breakers is elevated, and which are usually set to yield a product not larger than $\frac{5}{8}$-inch. After passing one or two sets of rolls, the ore is delivered to a trommel-system, having a mesh of $\frac{5}{8}$ and $\frac{1}{24}$ inch for the two extremes, and being four or, better, five in number. Each size of ore goes to a separate automatic jig, or pair of jigs, which are in most cases arranged to work through a bed of mineral of the next larger size, only the coarser sizes having a side discharge. The jigs have from three to four sieves, and are all, I believe, side-piston hydraulic jigs. A modification of the old Clausthal discharge is used to remove the concentrates in most cases, though the cap and tube has also some advocates.

The product of the first sieve should be always clean enough for smelting, while that of the second and third sieves is either recrushed or fed back into the machine. The pulp which passes through the finest sieve, $\frac{1}{24}$-inch, is either carried to the slime pits or fed direct to Frue vanners or tables; or, as in the Parrot mill, separated into equal-falling sizes by pointed boxes, and the product of each separator worked upon a separate vanner, which is by far the most perfect method.

The slimes which flow over the pointed boxes are caught in sumps or labyrinths, and either thrown away or used as they are. Being very siliceous, and yet often containing too much copper to lose, they form a very disagreeable product, and one that is apt to accumulate on the hands of the metallurgist.

I think the point of sufficient importance to mention a plan that I have adopted at the Parrot works, and which enables us to work up most of our slimes at virtually no expense. Every one accustomed to the management of reverberatory furnaces knows the large amount of sticky loam and clay that is required to lute up the side door of the furnace, especially after the jambs are well burned out, so that a wide crack on each side of the door has to be thus filled. Assuming a furnace to smelt five charges a day, thus necessitating the luting up of the side door an equal number of times, and allowing only 50 pounds dry clay to each luting—and this is far below the average on old furnaces—it will be readily seen that where from six to a dozen furnaces are in operation the amount of clay used reaches a surprising figure. Now, on taking down the side door, all this clay falls down upon the fresh charge, which is piled just under the door, and eventually finds its way into the furnace, where it adds a serious amount of barren quartz to a charge already probably too siliceous. A careful trial proved that the slimes would answer the same purpose as the clay; and now, instead of smelting a ton or more per day of barren loam, we have replaced it with an equally satisfactory material, carrying 10 per cent. or more of copper.

To return to the subject of concentration. It is impossible to furnish any figures that shall apply to the different mills with any degree of accuracy, but in order to give a general idea of the results obtained from those ores carrying a high percentage of iron pyrites, which includes the greater part of the ores at present submitted to concentration, I will submit the following figures as a reasonable average:

Results of concentration.

	Per cent.
Original amount of copper in the ore	12
Assay of concentrates from jigs	21½
Assay of concentrates from vanners	32
Assay of slimes saved	9 to 13
Assay of slimes lost (forming a very small percentage of the total ore)	6½
Assay of tailings (excepting slimes)	3⅓

Degree of concentration, 2.1 tons into 1.

The works now building will give considerably better results, the points principally selected for improvement being the recrushing and reworking of all the middlings and tailings from the coarser jigs; a great increase in the capacity and efficiency of the sizing apparatus, as well as a corrected scale of sizes for the trommels; the substitution of hydraulic separators of ample capacity for the finest trommels, thus enabling the slime jigs to work a product consisting of equal-falling instead of equal-sized grains, by which the amount of feed water is lessened, and the capacity of the machine greatly increased; the substitution of an ample number of sideshaking tables for an insufficient number of vanners, and a thorough sorting of the pulp by hydraulic separators before feeding to the tables. These improvements, supplemented by a more systematic and extensive effort to save such slimes as are worth smelting, are expected to considerably increase the efficiency of the works.

Want of space forbids any greater amplification of this subject; but I think enough has been said to show the mining public that the science of concentration is by no means neglected in Montana, and to convince the proprietors of patent concentrating machines that the tailing beds now forming below the Butte concentrators are no such mines of wealth as they have been considered by several persons of this description, but who have been speedily undeceived on trial.

For the sake of completeness, I must mention the concentrator belonging to the Montana branch of the Boston and Colorado Company, which I am informed runs a large portion of the time on the oxidized manganese-silver ores mentioned in the first section of this paper. It is reported that, while some of these ores are too heavy in manganese to render concentration applicable, and while others carry so much of their silver contents in the quartz gangue as to cause an unreasonable loss, the ores found in certain mines are extremely suitable for this purpose, and admit of the production of a concentrate high in manganese, and in which most of the silver is retained. This forms a most welcome addition to an establishment that labors under the disadvantage of an overwhelming amount of silica in its smelting charges.

Amalgamation.—I shall dispose of the first and second divisions of the Butte metallurgical establishments in very few words, as the processes employed are so universally known, and these especial works, namely, the Lexington, Alice, Moulton, Silver Bow, and other mills, have been so thoroughly written up as to render any description that I could furnish entirely superfluous.

The Dexter mill is, I believe, the only one in which raw amalgamation is now practiced, and the ores it is treating are becoming so base as depth is gained that the percentage of silver extracted is far from satisfactory. The tailings show a considerable quantity of argentiferous carbonate of lead, and are now being concentrated, yielding a product assaying in lead slightly above the percentage called for by the formula of that mineral, and from 30 to 40 ounces of silver per ton. So far as is yet known, a very small proportion of the silver ores of this county are suitable for raw amalgamation.

The second division includes the Alice, Lexington, and several other mills, which practice a chloridizing roasting followed by pan-amalgamation. The Stetefeldt, Howell, and Brückner roasting furnaces are all represented in this district, and, so far as I know, the results are good, and present nothing of a particularly unique or interesting character.

The enormous charges levied by the Utah and Northern railroad for transporting the salt, which is so necessary in silver milling, from Ogden to this point ($20 per ton, while coal is brought nearly double the distance for about $6 and coke is transported from Pennsylvania for about $18), effectually block any attempt to treat the low grade silver ores, which occur so abundantly in this district, and which, if it were not for this grasping policy on the part of the railroads, would possess a certain value, though they are of too low a grade to ever yield a profit except to those who are able to work them on a very large scale.

Smelting of silver and copper ores in reverberatories to a rich matte.—The third method employed in Butte is the smelting of silver ores with sufficient sulphureted copper ores to form a copper matte, small in amount, but very rich in silver. This is produced only at the works of the Colorado and Montana Smelting Company, and is shipped for further treatment to the parent establishment at Argo, Colorado. My knowledge of this smelter is limited to hearsay, and to my own general acquaintance with the process employed. As the chief object of these works is to concentrate the valuable contents of a great many tons of ore into a very few tons of matte, it will be readily seen that the two substances to be avoided in the furnace mixture are sulphur and copper. Fortunately, most of the silver ores carry very little base metal, and are either surface ores, entirely free from sulphur and copper, or so-called "dry" ores carrying only a small percentage of zinc or lead, and mere traces of copper. Certain varieties of these ores carry sufficient iron pyrites and zincblende to demand a calcination previous to smelting, but by far the larger part can be fused raw. These true silver ores are mixed at the furnace with copper-bearing silver ores from the Gagnon and other mines, in which, however, the percentage of copper is low, and the sulphur is mostly eliminated by an oxidizing roasting. It will be noticed that all the ores thus far mentioned consist principally of silica, with the exception of such argentiferous ores as come from the manganese district, and a careful examination even of these so-called "fluxing ores" will show that the larger proportion of even these ores carry far too much silica and too little oxide of manganese and iron to form an easily fusible slag by themselves, much less to assist in fluxing other still more siliceous ores. Judging by eye, I should say that the furnace mixture, as made at these works, contains a higher percentage of silica than at any other similar smelter in the United States. The charge is far too siliceous to admit of all the quartz being fused and dissolved in the slag. On the contrary, the upper layer of each pig of scoria, to a depth of several inches, will be found to consist of unaltered fragments of quartz, cemented together by a glassy and extremely siliceous slag of a very low specific gravity, and consisting, as far as I can judge, of a mixture of bi- and tri-silicates of manganese, iron, and lime, the latter being added as a flux. This method of smelting is technically called "soaking," as the metallic contents of each fragment of quartz are soaked out by exposure to intense heat and long contact with the layer of molten matte which has collected in the hearth of the reverberatory furnace. As unsatisfactory as it may seem to such metallurgists as are only accustomed to the homogeneous and thoroughly molten slag of the blast furnace, this procedure yields most excellent results, as I know by personal experience. The metal is almost completely extracted, and the saving of basic flux is simply enormous. I append the silica determination of a fragment of this slag, picked up on the railroad track, where it is used to ballast the roadbed. It came from the upper or more siliceous layer of the slag block, and closely resembled a certain basaltic porphyry which occurs on the slopes of the curious volcanic butte west of Bernalillo, New Mexico, and known all over that country by the name of El Cabezon (Big Head).

Analysis of reverberatory slag ("soaked").

	Per cent.
Total silica	86
Silica in unmelted fragments	24.6
Silica in the fused portion of slag	64.2
	88.8

Discrepancy, 2.8 per cent.

I am informed that wood alone is used as fuel in the five reverberatories which are employed in producing this silver matte. Also that a charge of 3 tons is usually smelted in six and one-half hours, though frequently much more time is necessary to fuse a charge containing an undue proportion of silica. It is also reported that each furnace is tapped once weekly, yielding about 3 tons of matte, varying greatly in value as the ores treated are richer or poorer. A sample assayed under my supervision contained 53 per cent. copper, 815 ounces silver, and 2 ounces in gold per ton. Judging from the figures already given it would seem that about 20 to 25 tons of ore are concentrated into 1 ton of matte. Much of the silver ore smelted at these works could be far more advantageously treated by chloridizing roasting and amalgamation, or by leaching.

Smelting true copper ores in reverberatories.—The fourth division of the Butte metallurgical works, the smelting of true copper ores in reverberatory furnaces, includes three important establishments, named in the order of their production: The Parrot Silver and Copper Company, the Montana Copper Company, and those furnaces (soon to be increased in number) running on ore from Clark's Colusa mine. Their product probably exceeds in value that of the other four divisions.

In cases in which I am doubtful, the statements here made must be taken as referring to those works with which I am personally most familiar. Private interests forbid as accurate and detailed description of the works and statement of expenses as I should be glad to furnish.

The ore, as it is broken in the mine, is divided on the spot into at least two classes—first-class ore, assaying from 20 per cent. upwards, which is ready for smelting, and second-class ore, assaying from 10 to 18 per cent., and containing so much siliceous gangue as to render necessary a preliminary concentration. In certain of the copper glance mines a still richer class is made, which is sacked and shipped abroad. The first-class ore occurring in lumps is spalled with hammers to the size of the fist, and, after screening to remove the finest, is roasted in heaps or stalls. The heap-roasting practiced at most of the works here differs in no wise, except possibly in carelessness, from the usual method, and when carefully carried out reduces the percentage of sulphur from about 30 to 6 or 7 per cent., though this result is by no means generally obtained at certain works.

Roasting in stalls.—The stalls, used solely at the Parrot smelter, are 6 feet broad by 8 feet deep; they are inclosed on three sides, and connected with a large culvert at the back, which enters a capacious and lofty chimney. The stalls are built in long double rows, back to back, to economize material, and, although not strengthened with either tie-rods or braces, last a good many years if the surfaces of the walls next the ore are kept well protected with a coating of clay mud. At the Parrot smelter they are formed entirely of slag blocks, cast in sand molds, and weighing about 100 pounds apiece. The stalls contain about 22 tons of ore, which is dumped into them from a car running on a track over the whole line; and after being covered with fine ore, are kindled in front, and then require little or no attention till ready. The amount of wood is only about one-fifth of a cord per stall, or one-hundredth of a cord per ton of ore. If more is used, a lump of matte of greater or less size will be found near the bottom of the kiln, and the roasting will be imperfect. By the fourth day the large fragments of ore, which are built up to form the front wall of the stall, are removed, and two or three tons of well-burnt ore can be taken away without injury to the rest, great care being observed not to cut in too far toward the center, or approach too closely the line of fire, which has as yet only extended a short distance into the body of the heap. Each day a similar amount can be removed, and by the twelfth day the kiln is empty.

In comparison with heap-roasting these stalls offer the following advantages: The waste caused by rain and wind and from scattering over the ground is much less. Only about one-eighth the quantity of wood is required to roast an equal amount of ore. The labor is much less, being about as one to two and one-half. Instead of tying up valuable ore for a month or six weeks, one can begin to use it on the fifth day, and in a fortnight it is entirely finished. If properly managed there is absolutely no raw ore left over after burning in the stalls; while in heap-roasting there is always a large quantity that must be reroasted. Even the fine covering, and the ragging just below it, can be thoroughly burned in stalls if a few baskets of bark or chips are scattered over the coarse ore before the fine covering is thrown on. The sulphurous smoke from stalls is mostly discharged high in the atmosphere through a tall chimney, thus avoiding the dense fumes that come from even the smallest ore heap.

I should be glad to enumerate the disadvantages of stall-roasting as compared with burning in heaps; but after a long experience with both methods, I have nothing to say on the other side, except that in case one has to deal with an ore carrying a very high percentage of iron pyrites, it is easier to prevent matting in heaps than in stalls.

To prevent disappointment, in case my testimony should give rise to experiments on the part of metallurgists who desire to escape the drawbacks of heap-roasting, I must particularly insist on the importance of having a strong draft, which, of course, presupposes a large flue, and a chimney of sufficient area and height. For a battery of thirty stalls, arranged in a double row, back to back, with a flue extending between the two lines, the main culvert should have an area of at least 4 square feet; while the chimney, with a corresponding inside area, should be carried to a height of 70 feet. With an insufficient draft, the roasting is delayed beyond all belief, and the percentage of sulphur retained in the ore after the completion of the process will be far from satisfactory. In case any considerable amount of matte is formed in the stalls, it should be broken into pieces the size of the fist, and when 50 tons or more have been accumulated, it should be roasted in heaps in very much the same manner as ore. A few necessary changes, however, must be made. The bed of wood should be thicker than for ore, and the matte pile should never be built more than 4½ feet high. It should have vents or temporary chimneys (formed by placing a couple of sticks of cordwood in a vertical position) at distances not greater than 6 feet from each other. Whatever fine stuff is formed in breaking the matte should be thrown on the heap in conjunction with the coarse, to prevent too strong a draft, and the sides of the heap should be well covered with fine roasted ore. A heap of 50 tons, prepared in this manner, will burn for six days, when the operation of "turning" may be begun, as one burning, or even two, is seldom sufficient for matte, which differs entirely from ore in this respect. It should be turned directly on to another bed of wood, prepared alongside of the original heap, taking care that the lump of molten matte which will always be found at the bottom of the heap is broken into small pieces and piled directly upon the fresh bed of wood. The second burning will take a week, and may be followed by a third if it is desirable to remove the sulphur as thoroughly as possible. The cost of each burning may be estimated at 65 cents per ton at present Butte prices of labor and fuel. If it is found profitable this roasted matte may be smelted by itself to produce a superior grade of copper, as the numerous burnings and meltings which it has undergone will have mostly eliminated the arsenic and antimony that it may have contained. As it is essential to add a certain amount of siliceous flux in smelting this material, any quartzose slags rich in copper that may be lying about the place will form the most advantageous addition, as the copper produced from them will be of the best possible quality.

In most cases the first-class ore forms but a small proportion of the material treated, and we now come to the principal ore from which the immense copper matte product of Butte is derived, namely, the concentrates obtained from the second-class ore. These usually contain about 20 per cent. copper, 30 per cent. sulphur, and 10 per cent. silica, the balance being principally iron; and they are thoroughly calcined in long furnaces, heated by wood, worked by two men on twelve-hour shifts.

Calcining furnaces.— The furnaces which have been built under my supervision are 64 feet by 16 feet outside, and have four hearths, each 14 feet long by 15 feet wide in the clear. The ore is charged from a hopper upon the hearth furthest from the grate, in quantities of 3,600 pounds, and in spite of the great length of the furnace it is at a bright red heat in two hours. Without going farther into details I will state that each furnace calcines 11 tons of ore in twenty-four hours, reducing the percentage of sulphur from 30 to below 4 per cent., and consuming exactly 2 cords of pine wood. These results are so favorable that the cost of calcination is reduced to about as low a figure as one could hope to attain with a successful mechanical furnace. Care is taken to prevent the formation of sesquioxide of iron, it being almost infusible and requiring a good deal of time and fuel before the reaction of the sulphides in the charge reduces it to a protoxide and fits it for combining with the silica present. In a blast furnace, of course, the powerful reducing atmosphere accomplishes this result at once, but in the reverberatory smelting, which we are now discussing, the point mentioned is of sufficient importance to be always borne in mind.

The concentrates are discharged through a square hole in the hearth nearest the fireplace into an iron car, and are dumped over a high wall into a paved inclosure convenient to the smelting furnaces.

Reverberatories.—Nearly all the reverberatory furnaces in Butte are constructed after the same model, and differ from the ordinary Welsh furnaces in the following particulars: The hearth is wider—11 feet and more; the grate is large, but very shallow, being little lower than the furnace hearth; the bridge is broad and low, and the roof high, so that the space between bridge and roof is much larger than usual; the arch pitches very strongly toward the skimming door, so that the vulcatory is low; but the trapezoidal hole connecting hearth with flue has an area more than 50 per cent. greater than is the usual custom; the flue is broad and high, and much better results are obtained by expanding it rapidly until it enters the stack; each furnace has its own chimney, about 55 feet in height, and with a somewhat larger area than the Welsh furnaces. An increase in height is of no advantage. Numerous and continued experiments have proved that the foregoing peculiarities are exactly suited to the fuel in use—a flaming, semi-bituminous coal from Wyoming, which seems only slightly removed from lignite. It is very light, has only a slight tendency to coke, and though ready enough to form massive clinkers if allowed, gives far better results when burned in a shallow layer, without the deep clinker bed which forms the chief peculiarity of the Welsh method of firing. With a consumption of 7 tons of this coal in 24 hours, 4¾ charges of 3½ tons each of ore can be smelted.

The slag and cleanings that are returned to the furnace are never counted in the quantity smelted. It is found advantageous to admit an additional supply of air through a series of holes in the roof over the firebridge, and as the best proportioned furnace will flame badly just after throwing a fresh fire, and especially after grating (which should be done thoroughly once in 24 hours), a hole 8 inches square must be left in the stack below the flue, by which sufficient air is admitted to cool the lining when the furnace is flaming. The average charge consists of about 60 per cent. calcined concentrates, 20 per cent. roasted first-class ore, and 20 per cent. raw ore, the screenings of the first-class ore being used for this purpose.

Works that possess no concentrator are obliged to use more or less limestone as flux, and I am informed that at few of the smelters is the calcination of the ore sufficiently thorough to admit of the addition of such a large proportion of raw ore as I have indicated.

The furnace is tapped after each third or fourth charge, yielding a matte assaying from 60 to 70 per cent. copper, and from 15 to 50 ounces in silver, according to the grade of ore. I am informed that at most of the works considerable difficulty is experienced in keeping the grade of the matte as uniform as is desired by the parties to whom it is shipped. To show that this uniformity is perfectly attainable, I append a list of successive shipments of about 15 tons each, taken from the books of the furnaces under my charge. I will also state that so far from having uniform material to work with, the ore varied both in quality and amount almost daily, and the charge seldom remained the same for three successive shifts. The time represented by these shipments was the first ten days of August, 1884.

Percentage of copper in shipments of matte from the Parrot works.

No.	Per cent.	No.	Per cent.
1	64.7	12	63.6
2	65.5	13	63.4
3	64.4	14	65.5
4	64.6	15	63.3
5	64.0	16	65.5
6	63.2	17	64.8
7	63.1	18	64.9
8	63.4	19	64.0
9	63.6	20	64.8
10	64.9	21	64.5
11	64.8	22	63.2

This list might be almost indefinitely continued.

Contrary to European experience and to the teaching of the principal mining schools of the world, the amount of copper retained in the slag is by no means excessive, considering the very high grade of the matte produced from this first smelting. I cannot answer for all the furnaces in this district, but the slag produced from those with which I am personally familiar seldom exceeds 1.25 per cent., and frequently falls to 0.9 per cent. About one-half the copper contents of the slag is present in an oxidized condition, the remainder being retained as inclosed granules of matte. The plate slag is always returned to the furnace, and all the other pigs are carefully examined and any valuable portions resmelted.

The great proportion of the slag here produced is a mixture of singulo and bisilicates of iron, very little lime or alumina being present, except when the former is added as a flux. At the Parrot works the slag approaches a singulo-silicate ,while at most of the other furnaces, so far as I can judge by eye, it is considerably more siliceous. The matte is in most cases crushed in a small rockbreaker to the size of a hen's egg, sacked, and shipped, in some cases to the Baltimore or New York refiners, in others to England.

On the whole, the reverberatory practice in this district is fairly satisfactory and economical; though, as I have found by experience, constant attention to the size and condition of the furnace flues and other comparatively trifling points is rewarded by results entirely out of proportion to the labor expended.

With all varieties of fuel, a constant watchfulness and correction of the ever changing proportions of the more important parts of a reverberatory furnace (such as the bridge, flue, vulcatory, etc.) is demanded, but I have never yet met a variety of coal where the results obtained seem to depend so greatly on these slight and apparently trifling points, nor where the furnaces were so sensitive to minute alterations. I have had a furnace suddenly fall off from bringing its charge in five hours to requiring eight hours for the same operation, and the changing the size of the flue by the addition or removal of an inch of material, again restore the five-hour period. And as such circumstances are the rule and not the exception, it follows that a very little carelessness or inattention on the part of the metallurgist may cause almost unlimited loss to the works. I have particularly emphasized this matter, as I feel certain, from my own observation, that it is not in all cases understood or at least not acted upon.

I have endeavored to make this point still more noticeable by reducing certain results, which have occurred under my own observation, to actual figures. Knowing the exact profit to the company on each pound of copper produced under ordinary circumstances, I have found by calculation that by increasing the area of the flue of a certain furnace by 10 square inches, it produces a greater profit daily of $57.30, and adding to this the amount of fuel saved by doing good work instead of poor, the total difference amounts to $68.77. Assuming that six furnaces (the average number in the principal works) have all been built on the same incorrect model, the sum advances to $412.62 daily, or $150,606.30 per year. While this state of affairs might not very probably occur, the calculation is far from being a fanciful one, and I hope may forcibly illustrate the immense importance of forcing every smelting furnace to do the best possible work of which it is capable.

Repairs.—While I am on the subject of economizing in furnace work, I may properly mention the immense waste of money involved in unnecessary delays in making repairs. That frequent and extensive repairs must be made on reverberatory furnaces is an unfortunate fact, but every possible means should be employed to lessen the evil, by shortening the time during which the furnace is idle. Every moment of delay adds heavily to the expense, not only in the item of wages, which includes those of the masons, helpers, laborers, and the whole gang of men belonging to that furnace, but still more in the cooling of the walls and bottom, which will take hours of time and tons of fuel to bring back to their normal temperature, delaying for an unreasonable time the next two or three charges, and almost certainly increasing the percentage of copper in the slags.

As it is idle to find fault without suggesting the appropriate remedy, I will describe briefly the method that I always employ when making any of the frequent and comparatively slight repairs that occur every six or eight weeks, and that do not render necessary the complete cooling down of the furnace. I refer to such trifles as building a new flue, putting in a vulcatory or front or side door jambs, or patching the lining of the stack. The day before the job is to be done, I carefully examine the extent of the proposed repairs with the furnace-mason, a man of experience, with whose assistance I can closely estimate the number of brick needed, and, what is of much greater importance, the number that require cutting, and the exact size and shape that they must be cut to.

Noting all this carefully down, I have an ample supply of bricks cut into the shape that will be needed, and when masons and materials are all ready, skim and tap the furnace as clean as possible, throwing in a fresh charge (if the stoppage is to be only of short duration) to protect the workmen from the heat radiating from the bottom, and begin immediately knocking in with long steel bars the portions of brickwork that are to be renewed, dragging the débris out of the furnace at once with scrapers. The cold charge is especially heaped in that part of the furnace that is to be repaired, and if any portion of the arch is to be rebuilt, it is very easy to form a proper pattern for the purpose by shaping the ore as required. The best and quickest masons should be chosen for this work, and if the job is a very hot one they must be relieved every half hour. In fact, I have found it sometimes necessary to keep a small stream of water playing on the masons' hands, faces, and feet for an hour at a time. If the brickwork or ore is too hot to stand on, nothing makes a better temporary flooring than old planks soaked in copperas liquor, which will remain cool, and will neither catch fire nor smoke. If the fire has been properly banked without being allowed to get too low, the furnace will be in full heat by the second charge, after a stoppage of two hours for repairs.

Smelting in blast furnaces.—The fifth and last division of the Butte processes includes the smelting of copper ores in blast furnaces, which is practiced only at the Bell smelter, though the new Butte Copper Company proposes to do all its smelting in this manner.

I am unable to give accurate details of the Bell furnace. It is a small water jacket, 36 inches in diameter at the tuyeres, and with a capacity of about 40 tons of charge daily, though the quartzose nature of the ore necessitates a heavy proportion of flux, consisting of an excellent limestone and a rather poor quality of bog iron ore. When the calcination has been sufficiently thorough, the matte produced will reach 65 per cent. in copper, but this is seldom attained in practice. I judge that the expense of smelting per ton at these works is about the same as at those where reverberatory furnaces are employed, the high price of coke as compared with coal ($20 to $9) nearly neutralizing the advantages commonly claimed for the blast furnace. By increasing the number of tons smelted per day, which could easily be done by putting on a heavy blast, and bricking the fine ore, which constitutes the greater part of the charge, and by diminishing or entirely doing away with barren flux, which can also be very easily accomplished by building a concentrator of sufficient capacity, I am firmly convinced that the blast furnace will hold its own here in comparison with the reverberatory, as it does nearly everywhere else in America when properly managed. So long as toy furnaces, with a capacity of 20 to 40 tons daily, are employed, just so long the reverberatory will take the lead. But when metallurgists learn that a furnace of reasonable size, smelting from 80 to 100 tons a day, will not only work with a less cost per ton for both labor and fuel, but it is also far easier to manage, will average much longer campaigns, and will reduce the cost of repairs from 3 to 6 cents for each ton of ore treated, then the reverberatory will remain in its proper place, which is in Swansea and nowhere else, unless almost similar conditions can be found elsewhere as regards price and quality of coal, fireclay, and labor, and a world's ore market to select from. The only other exception, in my humble opinion, would be where, with good fuel and very rich ore, the charge is necessarily so siliceous that in spite of concentration or fluxes the silica contents of the slag cannot be kept below 45 per cent.

The smelting capacity of this district will soon be more than doubled, as the new works of the Anaconda Company, Butte Copper Company, and Clark's Colusa will doubtless be in full operation. It will then be interesting to compare the work done with our present operations, and I feel convinced that the improvements contemplated and partially carried out in the new works just mentioned will more than meet any possible future decline in the price of copper, so that although many of the Arizona mines and a large proportion of the principal copper producers of both Lake Superior and Chili may find it necessary to suspend operations, Butte will still be able to keep every furnace in blast so long as the rich ores, which are still found in undiminished quantities in the lowest workings of the deepest mine, continue. And even if the percentage of the ore diminishes materially, its value in silver (in many cases equaling 3 cents per pound of copper), and the constant cheapening of freight, fuel, materials, and labor, make it probable that Butte's time of prosperity, even if dependent on its copper mines alone, will cover a period of too many years to make it possible to prophesy the time when it will cease to be one of the most important factors of the world's copper market.

THE CUPOLA SMELTING OF COPPER IN ARIZONA.

By James Douglas, Jr.

Furnaces.—The water-jacketed furnace is an actual necessity to the Western smelter, owing to the enormous cost of refractory building material. When the owners of the Longfellow copper mine in Arizona commenced smelting twelve years ago each firebrick cost them $1; and even now at the several furnaces in the Southwest firebricks cost from $100 to $200 per thousand. An indestructible furnace is therefore almost essential to economical success, and this the water-jacketed furnace practically is. It is an expansion of the water tuyere and water back, contrivances which have been long in use. In 1866 J. R. Grout, of the Detroit and Lake Superior Smelting Company, patented a cupola with cast-iron boshes, containing the essential features of the more recent furnace. But the exigencies of the period not requiring it, the general adoption of the water jacket only dates from 1873, when Willliams & Daggett introduced it for the smelting of copper and lead ores in Utah.

The type now usually manufactured for copper smelting is that which was designed by Mr. Lewis Williams, who is in charge of the Copper Queen furnaces at Bisbee, Arizona. The eminent success of that mine and its smelting operations gave a great stimulus to the mining of copper in the Southwest, and it was superstitiously believed that some peculiar advantage lay in the particular shape and size of the furnace used by Mr. Williams at the Queen, no matter what the ore to be treated might be. The Pacific Iron Works built the first Queen furnace, but other western and eastern machine shops soon competed for the trade and took out patents for immaterial modifications, advertising their trifling changes in construction as important innovations, and publishing the record of their furnaces when running on some exceptionally fusible ore, as if the quantity smelted were due to the peculiarities of the furnace, when in reality it depended on the character of the charge. No patent covers the use of an inner and outer metallic shell, between which water circulates in quantity sufficient to cool the inner shell, which is in contact with the smelting charge. Every smelter therefore may design a furnace of the proportion and shape he considers best adapted to the ore he has to treat, while any boiler maker may build it without fear of infringing any rights. As the jacket merely replaces the brickwork of the older furnace, it may be made of any shape and size. For siliceous ores it will be made high, for basic ores low. Most are round, and 3 feet in diameter at the tuyeres; but for certain ores the diameter may be advantageously increased. Others are oblong. Generally they have uniformly sloping sides; but one running at the Detroit mine (to be described hereafter in detail) is built with a bosh.

Smelting capacity.—The quantity of ore a jacket of given size will smelt depends upon the fusibility of the charge, the strength of the blast, and the supply of water. The 3-foot round jacket is usually designated as a 30-ton furnace. Under exceptionally disadvantageous circumstances a furnace of that size will smelt only 30 tons; but with fair ore and good management, as at the Queen and elsewhere, it smelts from 45 to 50 tons per day. On the very fusible ore of the Old Globe mine, at Globe, as much as 56 tons have been put through a 3-foot jacket, and even this quantity has been exceeded by a furnace at the Verde.

Unless the ore is refractory, 45 tons of mixture should be smelted under a blast of 10 to 12 ounces, produced by 100 to 115 revolutions of a No. 4½ Baker blower, provided the supply of water is ample. The latter condition is essential. To keep a 3-foot furnace cool under a high blast, from 37,000 to 40,000 gallons of cool water must be passed through the jacket daily, under a head of not less than 10 feet. If the flow be deficient or too hot, steam is generated, the cold water is pressed back, and steam will blow out of the discharge pipe till the jacket is nearly empty. Where enough fresh water to cool the jacket is not available, the hot issuing water must be pumped back and after cooling be returned to the furnace. The cooling is usually effected in a series of tanks. It is more rapidly done by pumping the hot water into a small cistern, elevated 15 feet or so above the receiving tank, through the perforated bottom of which cistern the water falls in streams unimpeded through the air, or better still, upon a brushwood or other open filter, which exposes a large surface to evaporation. When a furnace is first blown in, the iron shell is exposed to the full influence of the heat and more water is required than after the furnace has run a few hours, by which time a coating of slag protects the iron and a rim slightly deflects the blast from the periphery of the furnace. The issuing stream may be almost boiling, but where the water is very calcareous and abundant it is preferred to allow it to flow so rapidly through the jacket that it is only warm when discharged. Much less lime is thus deposited in the jacket and no more fuel is said to be consumed. When the flow of cold water is scanty, and cooling must be resorted to, it is well to couple the pump with the cold-water pipe, so that if the jacket steams obstinately a stream of cold water may be forced through it.

Round furnaces of greater diameter than 3 feet, if the ore is favorable, will smelt more than the smaller ones, though not generally in proportion to their area. Oblong furnaces whose shorter diameter does not exceed 3 feet come nearer to the duty of the small round furnace, area for area, than do large round furnaces. If the ore is not free smelting a furnace of greater diameter than 3 feet is very liable to become deranged, with the formation of a core. If, however, the mixture is fusible and does not contain much fine ore, the blast of a Baker blower, even that of a No. 4½, will penetrate to the center of a 4-foot furnace, though a No. 6 Baker is preferable where furnaces of that size are used. The advantage of a small furnace over a large one is that it is more manageable and if it becomes hopelessly deranged it can be blown in and out at less cost than a large one. On the other hand the record of the Detroit large rectangular furnace shows a slight saving in fuel in the large over the small furnaces, though this is not the case with the large round furnace of the Arizona Copper Company. Up to a certain point the staff necessary to handle the charges and slag of a small furnace would handle a somewhat larger quantity. There is, therefore, always an economy in this item, but unless the ore is very fusible and invariable in its contents this advantage is more than balanced by liability to derangement. In the round 3-foot furnace the cold water is generally admitted by 1½-inch tubing at four different points, two on opposite sides, and the hot water issues by two pipes inserted into the upper flange, rising some inches above the level of the jacket. The slag tap is also jacketed in the Queen furnaces. Where this is not done it is well to have a perforated tube above the slag and metal spouts, through which water may be sprinkled on the spouts and on the copper plates through which the slag and metal are tapped. It is found that crude copper cast in plates 1 inch thick is far preferable to brick for closing the slag and metal openings.

The pipes for admitting the cold water to the furnace should not force the stream against the inner shell, but be curved so as to direct the stream downward. The constant beating against the hot iron plates, especially if the water carries any sediment, rapidly perforates it. Most of the manufacturers have patented contrivances to assist the water in circulating, but unless absolute obstruction be interposed the water circulates without assistance. In building jackets the heads of the rivets should protrude as little as possible into the furnace, and no flange unprotected by water should be exposed to the heat.

Usual plant.—The smelting plant of the Copper Queen, at Bisbee, which is the pattern on which most establishments have been built, consists of:

1. A breaker, with jaws set to open 3 inches, run by a small separate vertical engine.

2. A screen below the breaker with bars ½-inch apart, to sift out fines. At the Globe and elsewhere the ore is dumped on a screen above the breaker and only that portion which is too coarse for the furnace is broken.

3. Bins into which the several varieties of ore are wheeled from beneath the breaker.

4. The Queen runs steadily two (nominal) 30-ton furnaces. This type of furnace is a section of an inverted cone, 3 feet in diameter at the tuyeres and 4 feet 6 inches at the feed door. The body of the furnace for from 6 inches below the tuyeres up to the feed door is built of inner and outer shells, 9 inches apart at the bottom and 4½ inches at the top, closed at top and bottom, within which the water circulates, and to which the water is admitted and from which it is discharged, as already described. The distance from the tuyeres to the feed door is 6 feet, and the total height of the jacket is therefore 6 feet 6 inches. The blast pipe discharges into a wind box, which nearly encircles the furnace and

supplies the tuyeres with a very even blast. A boiler-plate ring about 2 feet deep is riveted to the outer shell of the jacket, and this rests on a cast-iron plate provided with a drop bottom, which plate is supported about 2 feet above the floor of the furnace house on cast-iron pillars. This ring, lined with firebrick, constitutes the crucible of the furnace. The drop bottom is protected with the same material. The slag spout is secured to the crucible shell at the side of the furnace 10 inches below the tuyeres, and the metal spout is in like manner secured to the front of the furnace, 14 inches below the slag spout. The slag and metal openings in the shell are large and are closed by copper plates, each perforated with a small tap hole. Above the feed door the furnace contracts, and consists of an iron shell resting on the outer rim of the jackets, and lined with firebrick. At the Queen works, where much of the ore is soft and clayey, the furnace stacks discharge into a flue 3 feet wide and 96 feet long, provided with hoppers, which effectually catches all dust. In other furnaces the stack expands into a large cone, where, the draft being checked, the dust settles and is discharged through suitable ports. Elsewhere, as at the Arizona Copper Company's works, there is a regular brick dust-chamber. The space between the jacket shells at the bottom is wide enough to allow of the removal of the mud and scale through four hand holes. Where the water is very calcareous, scale accumulates so rapidly as to necessitate blowing down every week. At the Copper Queen the jackets are emptied every five weeks. If a circle of Ludlow gate valves were tapped into the jacket around the base, and these were successively opened to allow a stream of water not greater than that admitted to the jackets, washing out light sediment while heavy scale is being scraped out, the repeated blowing down and stoppage of the furnace might be avoided; which, though it does not cool the crucible, wastes time and coke.

The hood of some furnaces rests on the inner rim of the jacket and is not lined. Even when the hood is lined the number of firebricks which enter the crucible and hood need not exceed one thousand, and unless the charge is unusually basic or yields much matte, the bricks of the crucible need not be replaced during the lifetime of the shell, lute being applied when the furnace is blown out, and clayey ore being dropped in through the tuyeres, if the crucible walls need fortifying.

The rectangular furnace at the Detroit mine and the large round furnace of the Arizona Copper Company depart from the common type.

5. A No. 4½ Baker blower provides blast for each 3-foot furnace. Each blower at the Queen is driven by a separate upright engine, the quantity of blast being controlled by the speed of the engine, instead of by gate valves.

6. Usually six slag pots and four bullion pots are supplied with each furnace, but this number is insufficient. The slag pots wear almost indefinitely, but the bullion pots crack after a few taps, no matter how carefully clayed and heated before use. They are then strengthened by bands. It would probably be better to cast them in sections, mak-

ing the joints along the lines of greatest strain. At the Detroit works a copper core is cast in a pot of the usual size, and this is suspended in a larger pot, so that a space of 1½ inches intervenes between the core and the sides of the pot. Into this space copper is tapped, and thus a copper lining is secured which protects the iron wagon from the direct action of the hot metal. At the Queen slag is tapped every five or seven minutes, and the metal is run every half hour into bars averaging 250 pounds.

7. If there is an abundance of flowing water no tanks are required; otherwise, as at the Queen, a receiving tank, a pump, and cooling tanks form necessary additions to the plant.

8. At the Copper Queen Mr. Williams passes the slag from the furnace to the slag pots through an outer well 4 by 2½ by 2½ feet deep, made of cast-iron plates and mounted on wheels. The wells are lined with a plaster of clayey ore, and remain open for from twenty-four to forty-eight hours. Each well yields about 100 pounds of copper a day, besides what is entangled in the chilled slag. As the slag is tapped from the column of smelted ore, through which the particles of metal are constantly descending, it is inevitable that more or less metallic copper should issue with it. The outer well saves a portion of this mechanical loss, but as some of these almost invisible particles of copper in flowing into the well from the tap hole come into contact with the air and are oxidized, it is better to attach a settling well to the furnace itself and tap from it. This is done at the San Carlos establishment by bolting to the iron shell of the crucible a boiler-plate box 2½ feet long by 2 feet wide by 2 feet deep, supported on a pillar and furnished with a slag spout. The box is lined with brick, like the crucible of the furnace, the bottom sloping upwards from the level of the metal tap to that of the slag tap. This is covered by copper plates, which can be readily removed and replaced if the well requires to be cleared of chilled slags. It answers admirably the purpose intended without deranging the working of the furnace. Were it covered by a water-jacketed plate provided with a curtain which would dip below the surface of the slag at the discharge end of the well, like the tymp of the older furnaces, a continuous flow of slag might be secured.

9. The fine ore from beneath the grizzly, the dust from the flue, with the more clayey ore from the mine, are molded by hand into bricks with coke screenings after mixing in an ordinary pug mill. At the Detroit works, at Morenci, a brick press is used; and at the Arizona Copper Company's works, at Clifton, milk of lime is added to give greater coherence to the dust.

Operations at the Copper Queen.—The furnace operations at the Copper Queen have been marked by greater regularity in running and consequent uniformity of production, both as to quantity and quality, than those of any other establishment in Arizona. The following record from January 1 to October 31, 1884, gives the history of each of the two furnaces during that period:

Operations of furnace No. 1 at the Copper Queen mine, from January 1 to October 31, 1884.

Date, week ending—	Ore smelted.	Bricks smelted.	Total smelted.	Copper produced.	Copper yielded by ore and bricks.	Copper in slag.	Coke used.	Coke per ton of ore.		Coke per ton of copper.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*
January 7	542,390	97,060	639,450	66,090	10.35	1.70	124,214	19.43	385.4	188.0	3,760
January 14	588,360	73,250	661,610	70,515	10.70	1.69	126,860	18.87	377.6	177.8	3,556
January 21	644,620	18,250	662,870	70,805	10.66	1.45	131,679	19.86	368.6	186.0	3,720
January 28	590,900	56,500	647,400	69,880	10.73	1.45	123,345	19.33	380.6	178.9	3,565
February 4	643,070	34,930	678,000	71,370	10.51	1.10	125,455	18.70	370	176.0	3,521
February 11	682,460	8,500	690,900	68,450	9.91	1.44	126,134	18.21	365	183.4	3,694
February 18	656,800	29,000	685,800	72,685	10.57	1.45	128,910	18.92	375.8	177.9	3,558
February 25	608,250	61,650	669,900	77,305	11.72	1.34	130,672	19.44	388.2	168.7	3,374
March 3	580,080	94,860	674,940	78,185	11.59	1.07	122,965	18.20	364	151.6	3,033
March 10	622,800	35,100	657,900	68,825	10.72	.87	124,430	18.92	378.6	182.2	3,645
March 17	601,200	70,800	672,000	73,520	11.06	.85	130,145	18.19	386.2	178.4	3,568
March 24	555,600	94,500	650,100	70,425	10.82	.88	120,400	18.56	371.4	171.6	3,428
March 31	587,700	98,500	086,200	76,200	10.75	.91	128,724	18.88	372.2	167.6	3,210
April 7	618,900	70,500	689,400	78,570	11.36	.91	126,301	18.72	366.4	161.9	3,239
April 14	579,900	78,300	658,200	75,555	11.57	1.07	120,995	18.38	367.6	161.7	3,234
April 21	582,710	84,440	667,130	74,340	11.13	.95	125,377	18.96	376.4	168.0	3,361
April 28	568,690	128,690	697,380	80,005	11.58	1.00	125,154	17.64	352.8	155.5	3,110
May 5	566,370	96,880	663,250	70,980	10.53	.92	122,730	18.55	371.2	149.1	2,983
May 12	591,890	93,800	685,690	69,695	10.12	.80	123,916	18.63	347.4	178.0	3,560
May 19	575,043	95,760	670,803	69,910	10.41	.75	135,291	18.67	373.6	178.9	3,578
May 26	570,720	98,560	669,280	73,255	10.91	.78	126,213	18.85	377.8	174.7	3,481
June 2	543,170	98,560	641,730	68,325	10.69	.75	123,315	19.22	388.6	154.0	3,080
June 9	561,440	106,960	668,400	78,175	11.68	.88	127,649	19.02	381	165.9	3,318
June 16	563,470	106,400	669,870	76,463	11.68	1.07	128,235	19.12	381.6	167.6	3,353
June 23	544,860	124,600	669,460	75,595	11.24	1.12	126,501	18.94	378.2	167.9	3,358
June 30	566,801	131,880	698,681	87,390	12.49	1.27	121,627	17.41	349.6	139.7	2,652
July 7	518,911	84,000	602,911	70,995	10.08	1.11	104,170	15.66	293.2	121.5	2,516
July 14	612,021	108,080	720,101	78,665	10.79	1.20	123,932	17.21	344.2	157.8	3,701
July 21	627,095	85,120	712,215	72,875	10.19	1.41	124,621	17.78	350.4	171.5	3,429
July 28	637,714	97,160	734,874	81,425	10.99	1.38	104,170	15.66	393.2	149.9	2,885
August 4	587,202	100,240	687,442	79,100	11.49	1.32	114,626	16.70	334.2	147.1	2,975
August 11	608,018	78,120	686,138	68,120	9.89	1.18	116,424	16.98	339	177.0	3,461
August 18	579,453	112,280	691,733	69,500	10.10	1.10	116,932	16.89	337.8	169.0	3,380
August 25	652,925	32,480	685,405	68,000	9.93	1.22	116,730	17.02	340.4	158.1	3,449
September 1	680,190	38,640	718,830	76,595	10.73	1.40	120,942	16.81	336.2	159.3	3,186
September 8	691,511	53,864	745,375	93,540	12.52	1.31	117,771	15.69	315.8	126.1	2,523
September 15	645,900	77,100	723,000	92,980	12.82	1.20	115,645	16.06	321.2	124.1	2,512
September 22	631,200	89,400	720,600	08,565	13.69	1.20	114,801	16.03	363.4	116.8	2,337
September 29	673,500	87,600	761,100	111,870	14.66	.99	114,549	15.01	301.8	103.2	2,068

October 6	716, 700	43, 500	760, 200	102, 345	13. 46	1. 02	116, 309	15. 12	303. 2	110. 2	2, 212
October 13	726, 900	....	726, 900	90, 735	12. 43	1. 10	116, 791	16. 09	321. 8	130. 5	2, 610
October 20	737, 400	15, 900	753, 300	93, 135	12. 34	1. 19	112, 588	14. 94	298. 8	120. 9	2, 419
October 27	714, 600	42, 900	757, 500	97, 195	12. 81	1. 42	109, 372	14. 44	288. 8	112. 8	2, 256
October 31	345, 300	45, 300	390, 600	44, 130	11. 29	1. 42	60, 577	11. 15	340. 4	124. 3	2, 751
	26, 724, 474	3, 279, 814	30, 004, 568	3, 382, 302	11. 24	1. 16	5, 310, 870	16. 85	352. 4	156. 6	3, 127

Operations of furnace No. 2 at the Copper Queen mine, from January 1 to October 31, 1884.

Date, month ending—	Ore smelted.	Bricks smelted.	Total smelted.	Copper produced.	Copper yielded by ore and bricks.	Copper in slag.	Coke used.	Coke per ton of ore.		Coke per ton of copper.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*	*Pounds.*
January 31	2, 633, 410	277, 960	2, 911, 370	308, 735	10. 60	1. 57	560, 255	19. 22	384	181. 7	3, 635
February 29	2, 666, 260	169, 340	2, 835, 600	304, 315	10. 70	1. 41	533, 590	18. 81	376	176. 2	3, 525
March 31	2, 673, 840	354. 000	3, 027, 840	330, 405	10. 86	. 92	564, 683	18. 65	373	171. 8	3, 437
April 30	2, 516, 930	389, 210	2, 906, 140	324, 705	11. 14	1. 06	532, 140	18. 31	366	164. 3	3, 287
May 31	2, 520, 100	424, 280	2, 944, 380	307, 790	10. 42	. 86	547, 391	18. 59	372	178. 3	3, 566
June 30	2, 364, 335	488, 600	2, 852, 935	332, 000	11. 60	1. 07	532, 663	18. 70	370	161. 8	3, 237
July 31	2, 644, 549	427, 560	3, 072, 109	331, 395	10. 74	1. 37	524, 054	17. 07	341	158. 7	5, 175
August 31	2, 826, 761	298, 880	3, 125, 641	314, 240	10. 11	1. 38	524, 962	16. 77	335	166. 5	3, 359
September 30	2, 841, 830	328, 500	3, 170, 330	422, 990	13. 32	1. 20	500, 118	15. 77	316	119. 3	2, 387
October 31	2, 961, 150	144, 650	3, 105, 800	398, 720	12. 87	1. 23	495, 340	16. 15	320	126. 3	2, 553
Total	26, 649, 165	3, 302, 980	29, 952, 145	3, 375, 295	11. 21	1. 27	5, 315, 196	17. 70	355	160. 49	3, 216

Furnace No. 1 had been in blast two years on September 16, 1884. During that period its crucible had never been cooled. It had been blown down every five weeks to clear out the lime scale from the jacket, but each operation occupied, from the blowing down to the refilling, only three hours. Once this interruption was extended to six hours, when a patch was riveted to the inner shell opposite to one of the water pipes. No. 2 furnace had been continually in blast since May, 1883. During these long campaigns not a brick had been used in repairs. Both furnaces are of the same size and pattern, the only difference being in the diameter and dip of the tuyeres. Those of furnace No. 1 are 5 inches in diameter and have a slight dip; those of No. 2 are 4 inches in diameter and are set horizontally. The blower of furnace No. 1 is run at 115 revolutions; that of furnace No. 2 at 105, to maintain a pressure of about three-fourths of a pound. The furnace record shows a decided advantage in favor of the 5-inch tuyere, the slags being cleaner and the amount of ore smelted being greater.

The coke used is from Trinidad, Colorado, and San Pedro, New Mexico. The latter is freer from ash but more friable than the former. The consumption of coke is large, 1 part to 5.9 parts of wet ore, as fed into the furnace. The ore contains on an average not less than 10 per cent. of moisture. The charge requires to be occasionally fluxed, but generally a judicious mixture of ores from the several levels, which yield ores of very different composition, relieves the furnace from any barren material.

The furnace staff consists of a day and a night foreman, twelve hours each, over both furnaces. To operate each furnace:

No.	Class.	Length of shift.
		Hours.
3	Ore wheelers	8
2	Coke wheelers	12
3	Feeders	8
3	Tappers of slag and metal	8
4	Helpers, wheeling slag and metal	12

The ore wheelers and coke wheelers are Mexicans. One Mexican is employed in the coke yard in cleaning bullion and wheeling up slag to the feed floor. One Mexican and six boys are intermittently employed making bricks (adobes). The furnace charges weigh 300 pounds, the ore, slag, flux (when used), and coke being carefully weighed on platform scales at the feed door. If the charge is unusually basic the crucible becomes thin and the iron casing and drop bottom too hot. The crucible is then emptied, and fine clay ore is inserted by a scoop through the tuyeres, until the crucible lining is sufficiently built up. If, on the other hand, the bottom rises, the blast is occasionally allowed to blow for a few minutes through the metal tap. A hammer is seldom used in tapping, and a bar never enters the tuyeres, an iron plug being inserted, which arrests the blast as soon as chilling is perceived at any point. The long campaign of these furnaces, their absolute freedom from accident, and the small bill of repairs, are due to the skill and the watchfulness of Mr. Lewis Williams.

The last annual report of the Copper Queen Company, made by Mr. Benjamin Williams, the superintendent, shows that since the commencement of operations in the summer of 1880 until April 1, 1884, there were smelted 89,385 tons of ore, yielding 12,048 tons of black copper, of an average percentage of 96.50 by fire assay, or 13.45 per cent. of black copper to the ton of ore. This large yield was produced by one 3-foot furnace for the first year and by two furnaces subsequently. A spare jacket is always ready, but it is not deemed necessary to keep a third furnace set up, as accidents are rare, and when a jacket is worn out it can be quickly removed and replaced by another.

The following analysis of samples of slag taken over a period of several months indicates the character of the charge, which consists of calcareous surface ores carrying chiefly green carbonates, brecciated clays, silts saturated with carbonates, and massive iron oxides impregnated with cuprite, which are intercalated among the clays in the lower levels of the mine.

Analysis of Copper Queen slag.

	Per cent.
Silica	26.64
Protoxide of iron	42.60
Manganese	0.30
Zinc	0.50
Lime	9 51
Magnesia	0.20
Alumina	15.40
Copper, carbonic acid, etc	4.85
	100.00

Old Dominion Copper Company.—The second largest producer of copper during the last two years has been the Old Globe mine, at Globe, worked by the Old Dominion Copper Company, of New York City. The output has in some months considerably exceeded that of the Copper Queen. The total production for 1884 was 7,396,725 pounds of copper from 23,362 tons of ore, which therefore yielded 15.83 per cent. The assay value of the ore was 17.33 per cent. The plant contains three furnaces, all of which are seldom run together. In construction the plant does not in any important feature differ from that of the Copper Queen, at Bisbee, and the furnaces are run on the same system. The ore, however, being more ferruginous, a more fusible mixture can be economically made. The 3-foot jacket has there put through as much as 56 tons daily. The experiment of running a 3-foot furnace with two No. 4½ blowers was made, but resulted in an increased duty of only 4 tons per day.

Works of the Detroit Copper Company and the Arizona Copper Company.—At Clifton is the large smelting plant of the Arizona Copper

Company, the nearest of whose mines, those of the Longfellow group, are adjacent to those of the Detroit Copper Company, 5 miles distant up Chase creek. The Detroit Company's smelting works are at its mines, where the little town of Morenci has grown up. Both establishments have substituted large for small furnaces.

The old smelting works of the Detroit Company were on the San Francisco river, 5 miles below Clifton and 7 miles from the company's mines, which are at an elevation of 1,450 feet above the river and in a perfectly sterile region. The furnaces on the San Francisco were run by water power, but as the cost of transporting ore by teams was considerable and the interruptions frequent, it became necessary either to connect the mines with the works by a railroad or to move the furnaces to the mines and pump thither the water with which to cool the jackets. The latter alternative was decided on. The power which formerly ran the furnaces, a 44-inch Leffel turbine, under a 10-foot fall, is now applied to a powerful pump. The pump was designed by H. R. Worthington, and combines as perfect simplicity of form as is compatible with the strength necessary to a very heavy lift. It has four single-acting water plungers, 5½ inches in diameter, 15-inch stroke, that make it equal to two double-acting pumps. The valve chambers are multiplied. They can thus be small and separate, easily replaced, and be much stronger than one subdivided chamber would be. The pump was designed to throw 100,000 gallons per day, at twelve strokes per minute, through a 4-inch pipe, to an elevation of 1,510 feet and a distance of 7 miles against a pressure calculated at 750 pounds per square inch. The tubing between the pump and the mine is the ordinary 4-inch lap-welded pipe with extra heavy connections and valves at the bottom of the column. The pump is not run faster than nine strokes per minute; at that speed the requirements of the camp and furnaces are more than satisfied. Running at from five to six strokes the pressure gauge indicates from 640 to 670 pounds. The actual elevation from the pump to the top of the store tanks, which are some distance above the furnaces, is 1,540 feet.

There is one other instance in Arizona where pumping has replaced the transport of ore. The Arizona Central (the old Vulture) gold mine pumps the water for an 80-stamp mill from the Hassayampa, a greater distance but to a less elevation. Steam power is there used, yet the cost is only 25 cents per ton of ore stamped against $4 for haulage. The economy of throwing water over transporting ore is so self-evident that it should be oftener practiced. As pumps and tubing can be built to withstand almost any strain, and are operated in the oil region under a pressure of over 1,000 pounds to the square inch, the localities where the system can be applied are very many. The makers state that the type of pump above described has proved itself perfectly capable of dealing with pressures as high as 5,000 to 6,000 pounds per square inch.

The Detroit smelting works are connected with the company's mines and with the Arizona Copper Company's tramway to Clifton, and with the terminus of the branch railroad to Lordsburg, by a system of 20-inch gauge tramways. Thus all wagon hauling and unnecessary handling of ore, coke, or bullion is avoided. As the companies have adjacent mines the mine roads have been built jointly and are used by both—an example of harmonious co-operation worthy of imitation. The mine tramways, on which two engines are kept busy, are 1½ miles in length and traverse 2,300 feet of tunnels.

At the Detroit works two furnaces are erected, one the usual 3-foot round stack, the other a large rectangular furnace, with a bosh, designed by Mr. Carl Henrich, the late metallurgist. The cross section at the tuyeres is 33 by 66 inches, which it maintains for 10½ inches upward, then the sides slope rapidly, so that at 30 inches above the tuyeres and 3 feet above the slag tap the cross section is 45 by 78 inches. Here the lower jackets, four in number, terminate, and the upper four jackets, 5 feet high, rest on them, with a lower pitch, so that at 8 feet above the slag tap the section is 54 by 87 inches, which size is retained to the feed door, 11 feet above the slag tap. The crucible is 14 inches deep, is brick lined, and is provided with a drop bottom.

The furnace was built with an adjustable modification of the bell and hopper automatic feed, but it had to be taken out, as it was found to size the ore and throw an undue quantity of fines either to the rim or center as the case might be. Mr. Henrich adopted the bosh, believing that by reducing more iron he would clean his slags, an inference which seems to have been borne out by the short experience as yet had; but the furnace shows a greater liability to scaffold than the usual inverted-cone type. It is provided with fourteen tuyeres, five on each long side and two at each end. The tuyere gates are 9-inch vertical slots, and the tuyeres are connected by canvas bags with the blast pipes, and can be adjusted both as to height and pitch, as in the Western lead furnace The tuyere openings are only 2¾ inches. The blast is supplied by two No. 4½ Baker blowers, run at 115 revolutions to produce a pressure of 10 ounces. A larger quantity of air would probably increase the efficiency of the furnace to 100 tons per twenty-four hours, which its large area calls for. The slag is tapped from both ends, the metal from the middle.

The record of twenty-six days' run in November, 1884, is as follows:

Record of the Detroit large furnace, November, 1884.

Beds.	Weights.		Copper in ores.	Copper produced.	Copper saved.	Copper in slag.	Colorado coke used.	Fuel ratio.
	Pounds.	*Per ct.*	*Pounds.*	*Pounds.*	*Per ct.*	*Per ct.*	*Pounds.*	
Ores	3,292,575	14.57						
Iron	823,570	5.05						
Total ores	4,116,145	12.75						
Limestone	314,625							
Total charged	4,430,770	11.85	525,087	492,035	93½	1.11	676,385	1 to 6.55

Or dry ore and flux smelted per day, 85.19 tons; black copper produced, 18,946 pounds per day.

The record shows a reduction of the copper in the slags of about 0.4 per cent. under the average working of the 3-foot round furnace, and a saving in coke of about 8 per cent., the consumption of San Pedro coke by the small furnace being about 1 to 6 of smelting mixture. When Cardiff patent pressed coke is used the small furnace consumes only 1 to 8. Tennessee coke is about to be tried at these furnaces, when comparison can be made between the coke from Trinidad, Colorado; San Pedro, New Mexico; Cardiff, Wales; Connellsville, Pennsylvania; and Tennessee.

The labor employed about this furnace is:

Above: When using the automatic feeder: 6 coke and ore wheelers (length of shift, 8 hours); 2 weighers (12 hours).

Their place is taken by 3 feeders (8 hours) when the automatic feed is not used.

Below: Three metal tappers and wheelers (eight hours); 6 slag tappers and wheelers (eight hours).

Were the capacity of the furnace increased to 100 tons daily the present staff would not be able to overtake the work. Yet the labor is less per ton of ore treated than is necessary to handle the small furnace, running say 40 to 50 tons a day. As the area of the large furnace is as 15 to 7.06 compared with that of the 3-foot furnace, it should smelt about 100 tons. Mr. Church, who is both manager and president of the company, introduced another modification into the works, which is a decided improvement. Instead of a number of small engines, he uses one 12 by 36-inch Corliss engine, built by Fraser & Chalmers. It consumes only 1¾ cords of wood per day in running the two blowers, rock breaker, sampling mill, elevator, etc. Its speed is, of course, invariable. All the coke screenings, which are however trifling when English coke is used, are burnt under the boilers. The blast of the furnace is regulated by gate valves.

The ores to be smelted come from four claims, and are very different in character and variable in composition. They are consequently made into beds, 15 feet wide by 36 feet long, containing 250 tons each, the contents of which are carefully sampled before use, and any deficiency in base is made up from the flux bins. The following analysis of the average sample of slags was made by Mr. S. James, jr.:

Analysis of Detroit slag.

	Per cent.
Silica	34.34
Protoxide of iron	32.27
Manganese	6.24
Lime	10.13
Magnesia	2.30
Alumina	11.64
Copper, carbonic acid, alkalies, etc	3.08
	100.00

The Arizona Copper Company's works at Clifton far exceed in size any in the Southwest. They are built at the junction of the Chase Creek cañon, through which the company's railroad conveys the ore from their mines to the San Francisco river, which supplies water power. The railroad tracks to distribute coke and ore at appropriate levels are laid on terraces cut out of the rock, and the cars are discharged into four rows of coke and ore bins. A switch enters the bullion yard. The plant consists, besides, of two large rock breakers, three round furnaces 4 feet in diameter, two round furnaces 3 feet in diameter, three No. 7 Baker blowers, one No. 5 Baker blower, one No. 4½ Baker blower.

The works are run by water power during the greater part of the year, which can be supplemented by steam power in the dry season. As yet the whole battery of furnaces has not been in blast at one time. They have a total capacity of 300 tons of smelting mixture a day. Here large and small furnaces are run side by side, and Mr. Colquhoun, the metallurgist, gives his verdict unhesitatingly in favor of the small ones. He does not find the large furnaces more economical in fuel than the small, nor do they do cleaner work, while their greater liability to derangement more than compensates for a slight economy in the item of labor.

The large furnaces had jacketed crucibles lined with brick, till Mr. Colquhoun, attributing much of the faulty action of the furnaces to the chilling effects of the water where not needed below the zone of fusion, turned it off. The result was an immediate increase in duty from 60 to 75 tons of smelting mixture per day.

The charges of both the large and the small furnaces are alike, 730 pounds, this large charge being preferred as it reduces the errors in weighing, though the experience of other works favors smaller and often-repeated charges.

When Connellsville coke alone is used it is consumed in the proportion of 1 to 7.75 of mixture, while Cardiff patent coke smelts at the rate of 1 to 8.33. The ores of the whole region, except those of the Longfellow and Copper Mountain mines, in which large quantities of iron and manganese accompany the copper, are siliceous and aluminous, the carbonates and oxides being inclosed in decomposed feldspathic rocks. Both the Detroit and Arizona copper companies have therefore to use flux liberally.

Both works also make matte occasionally, which is also the case with the Copper Queen. At the Arizona Copper Company's works the pigs are dumped into water, which facilitates the removal of adhering matte and slag.

The United Verde Copper Company.—The only other establishment in Arizona producing copper largely is that of the United Verde Company. It has consisted heretofore of one 3-foot furnace, but another is now being erected. The ores treated are more argentiferous than any smelted in Arizona, the silver constituting a large proportion of the value of the bullion. The furnace went into blast in July, 1883, and ran 119⅝ days in that year, during which time it turned out 1,004 tons of bullion and matte, containing 940 tons of fine copper and 125,000 ounces of available silver, from 5,004 tons of ore. The consumption of Colorado and English coke mixed was 1,018 tons, or nearly exactly in the ratio of 1 to 5.

In 1884 the furnace ran for 231¾ days. The product was bullion 1,268 tons, containing 1,208 tons of refined copper and 134,676 ounces of silver, and 839 tons of matte, containing of refined copper 551 tons and of silver 25,416 ounces. This product was recovered from 12,067 tons of ore, which therefore yielded to the furnace 14.6 per cent. of copper. The bullion now coming forward contains also a noteworthy amount of gold.

On the Colorado river, above Yuma, copper was mined twenty years ago at the Planet and other mines, and was shipped as ore to California. A smelter has recently been erected to reduce the ore of these old mines, and has shipped some bullion; but the very low price of copper makes it difficult to work a lean ore to a profit, no matter how cheaply it can be mined.

No discoveries of new copper mines were made in 1884. Two new smelting works were started in new localities, though on old locations, but were soon shut down after producing a few car loads of bullion, and there are no projects on foot for the establishment of others. There is therefore no present prospect of any notable increase in the production of Arizona; but, on the other hand, there are no symptoms of any falling off, for never at any of the above named districts were more oxidized ores in sight than at present. The low price of copper of course reduces the profits, but this is being partially counterbalanced by reductions in every item of cost. The value of copper bullion shipped from Arizona exceeded in 1884 that of her gold and silver production, while its bulk and the freightage on the consumed coke render it as an article of export far more necessary to the prosperity of the railroads competing for the traffic of the Territory than many times its value in the precious metals. All interests and classes, therefore, are united in fostering an enterprise which has become an integral part of the industrial life of the Southwest Territories, and all therefore combine to help the Arizona copper miner and smelter to hold his own against all competitors in the present fierce struggle for existence.

While the copper from Copper Queen, Clifton, and Old Globe is remarkable for its freedom from arsenic, antimony, and other deleterious substances, the same is not true of all Arizona copper, nor even of copper made from other mines in the immediate neighborhood of some of these mines, but the Copper Queen and some other brands are so remarkably pure as to have acquired a high reputation both in the American and European markets. All the furnaces turn out bars of about equal tenor in copper, namely, 97 to 98 per cent. by wet assay.

[A paper by Mr. Henry M. Howe, on "Copper Smelting," prepared for this volume, has been omitted for lack of space, and is published separately as a bulletin of the United States Geological Survey.]

LEAD.

THE LEAD INDUSTRY OF THE UNITED STATES.

By C. Kirchhoff, Jr.

Since the last report, for the year 1882, the development of the lead-producing industries of the United States has been on the whole a quiet one, without any exceptional occurrences to permanently disturb the work of extraction, preparation, or marketing.

During the years 1883 and 1884 the cost of production of lead has been undoubtedly cheapened so far as those processes are concerned which may be considered as fairly independent of accidental causes. In the case of the actual mining of the ore the causes affecting each individual mine of course vary so widely from year to year that it is impossible to follow them or to draw general conclusions. Wages have declined in some quarters to a certain extent, and the introduction of the tribute system has in some instances led to a lowering of the cost of mining. In smelting and desilverizing costs have undoubtedly declined. The material is however handled by so many different concerns from the time when it is broken in the mine until it is delivered as refined lead in the markets that it is practically impossible to make even a guess at the limit at which profitable work ceases, or in other words what point a downward movement of values can reach without leading to a material curtailment of production. As a general thing it may be stated that thus far there has been no serious pressure, except possibly in the Missouri districts. The past has clearly shown how low prices may fall before forcing a suspension even there, and the improved facilities in the Rocky Mountain districts since the days of the great decline in the spring of 1879 have enabled them to better resist low prices. On the other hand ores are now mined and marketed which then would have promptly traveled on to the dump. This involves of course greater outlay for mining, dressing, and smelting plant, and the margins on low grade ores are much smaller and more seriously affected by a decline in the value of the base or the precious metal. It is true that the average life of a mine is longer; the actual quantity of metal it furnishes till the time of its exhaustion or abandonment is greater, and in that sense the silver-lead mines in the far West have gained in stability. Notwithstanding this, it is true to-day as it has been in the past that the total production of the country, and to a large extent the values of lead, have been dependent upon the fortunes of a comparatively few large mines. At one time the sudden development of the Nevada mines depressed the markets. Then Utah came forward with large quantities, and finally Leadville rushed into prominence. A few figures will illustrate this point. In 1883 the following mines produced the quantities stated:

Lead ore and lead produced by the following mines in 1883.

Mines.	Ore.	Lead.
	Short tons.	*Short tons.*
Iron Silver, Leadville, Colorado	92, 271	22, 712
Horn Silver, Frisco, Utah	42, 663	14, 970
Silver Cord, Leadville, Colorado	26, 179	6, 104
Eureka Consolidated, Eureka, Nevada	14, 144	1, 397
Richmond, Eureka, Nevada	19, 611	3, 256
Morning Star, Leadville, Colorado	12, 000	4, 200
Evening Star, Leadville, Colorado	11, 000	2, 200

The figures for other large mines are withheld because they are confidential, but there are many individual producers turning out more than 2,000 tons per year.

With consumption so closely following production in this country the dropping out of the list of one of the larger mines, or of a number of the smaller ones, would not be without its direct influence upon values. On the other hand the appearance of new producers, or of the opening out of large bodies of ore in old mines might easily lead to an overstocking of a market which is very sensitive. One feature deserves special mention because it began to exert its influence in 1883 and was even more marked in 1884. Two large smelting companies, one in Colorado and one in New Mexico, and to a less marked degree other concerns, have made the basis of their operations the working, each of them, of a mine containing large bodies of lead ore comparatively poor in silver. With a control of the desired quantities of heavy ores, they are in a position to work at an advantage "dry" ores, the chief value of which is their silver contents, the lead being low or entirely absent. This movement, rendered possible by better railroad facilities and careful metallurgical management, makes deposits of lead ore available which thus far were considered too poor to work, and practically opens out a new source of the supply of the metal. It has in the past year fully covered the deficiency caused by the falling off in some districts.

The centralization of smelting operations has gained a good deal of headway during the years 1883 and 1884. Ores are now carried long distances by rail, and much material that formerly was crushed in amalgamating mills now goes to smelting furnaces. This interchange of raw materials between the different States and Territories makes it a difficult matter to trace the lead to its source, a matter to which reference will be made further on.

The factors which have developed greater significance during the past year, and which singly or jointly have contributed to lowering the cost of the production of lead, of widening the area from which supplies are drawn, and pushing downward the minimum grade available for utilization, may be thus summed up: The railroad system of the far West has been extended, and the coal resources, notably so far as coking fuels are concerned, have been well developed; concentrating works have been built in many districts with eminent success; smelting has been centralized, and is now conducted generally by well-trained metallurgists, and the business has been expanded by combining with it the purchase from many quarters of both low and high grade refractory silver ores. Good markets have been made available to small producers, facilitating development work without the outlay of heavy sums of money for equipment. All these factors have contributed to making the supply of lead more and more independent of the fluctuations in the yield of a few large mines or groups of mines. It will tend to counteract the danger of a sharp restriction of the supply now imminent through the falling off in the product of the two largest lead mines, past and prospective. During the years 1883 and 1884 no new districts have been opened which might justify the belief that the market is to be flooded at short notice with heavy amounts of metal. But there has been a large and steady progress in opening out in many parts of the Rocky mountains, which, in the aggregate, promises to fill any gaps that may be caused by a decline in the make in some localities.

Although there has been much complaint of low prices, the latter have evidently not touched figures that may be looked upon as prohibitive, and wages and freights are still at a height from which a marked reduction is possible without causing suffering.

A very encouraging feature of the history of the lead trade during the past two years has been the heavy consumption, which has steadily kept pace with the output in the face of a general industrial depression. There seems little doubt that even a slight falling off in the production, or a fair recovery of business to normal activity, would promptly carry values upward.

One fact against which the western producers have had to contend during the past two years has been the steady fall in the price of silver. How largely this affects the lead mines may be gathered from the fact that returns from a number of refiners, whose lead product from base bullion in 1884 aggregated 117,608 tons of the total of 119,965 tons, turned out 21,505,248 ounces of fine silver and 146,830 ounces of fine gold. Of course a fairly large percentage of this quantity of the precious metals was obtained from purely silver ores, worked by lead smelters, but it is probably not far from the truth to estimate that fully 19,000,000 ounces of silver and 125,000 ounces of gold were obtained from lead ores mined in the Rocky Mountain States and Territories.

PRODUCTION.

On the whole, as a glance at the following table of the production of lead for a long series of years will prove, there has been a steady increase, especially during the past decade, in spite of some sharp fluctuations in values. The figures from 1825 to 1853 are those published by Whitney; those for the later years have been collected by Mr. Edward A. Caswell, of New York City, who has personally undertaken the task of gathering annually the statistics of production since 1873 with a sagacity and painstaking care which have caused them to be accepted as authoritative by the trade. Since 1882 the figures are those collected by this office.

Up to the year 1873 no specific data concerning the relative output of the different producing districts were available. For the succeeding years the quantities of desilverized lead and of non-argentiferous lead and the percentage of the former in the total have been added because they reveal clearly the growing importance of the former industry, which has its seat in the Rocky mountains; while almost the whole of the non-argentiferous lead is produced in Missouri, Kansas, Illinois, and Wisconsin, only a small quantity being made in Virginia. In this table, and throughout this paper, the tons are short tons of 2,000 pounds.

Production of lead in the United States.

Years.	Total production.	Desilverized lead.	Non-argentiferous lead.	Percentage of desilverized lead.
	Short tons.	*Short tons.*	*Short tons.*	*Per cent.*
1825	1,500			
1830	8,000			
1831	7,500			
1832	10,000			
1833	11,000			
1834	12,000			
1835	13,000			
1836	15,000			
1837	13,500			
1838	15,000			
1839	17,500			
1840	17,000			
1841	20,500			
1842	24,000			
1843	25,000			
1844	26,000			
1845	30,000			
1846	28,000			
1847	28,000			
1848	25,000			
1849	23,500			
1850	22,000			
1851	18,500			
1852	15,700			
1853	16,800			
1854	16,500			
1855	15,800			
1856	16,000			
1857	15,800			
1858	15,300			
1859	16,400			
1860	15,600			
1861	14,100			
1862	14,200			
1863	14,800			
1864	15,300			
1865	14,700			
1866	16,100			
1867	15,200			
1868	16,400			
1869	17,500			
1870	17,830			
1871	20,000			
1872	25,880			
1873	42,540	20,159	22,381	47.7
1874	52,080			
1875	59,640	34,909	24,699	58.5
1876	64,070	37,649	26,421	58.8
1877	81,900	50,748	31,152	62.0
1878	91,060	64,290	26,770	70.6
1879	92,780	64,650	28,130	69.7
1880	97,825	70,135	27,690	71.7
1881	117,085	86,315	30,770	73.7
1882	132,890	103,875	29,015	78.3
1883	143,957	122,157	21,800	84.8
1884	139,897	119,965	19,932	86.4
Total	1,873,134			

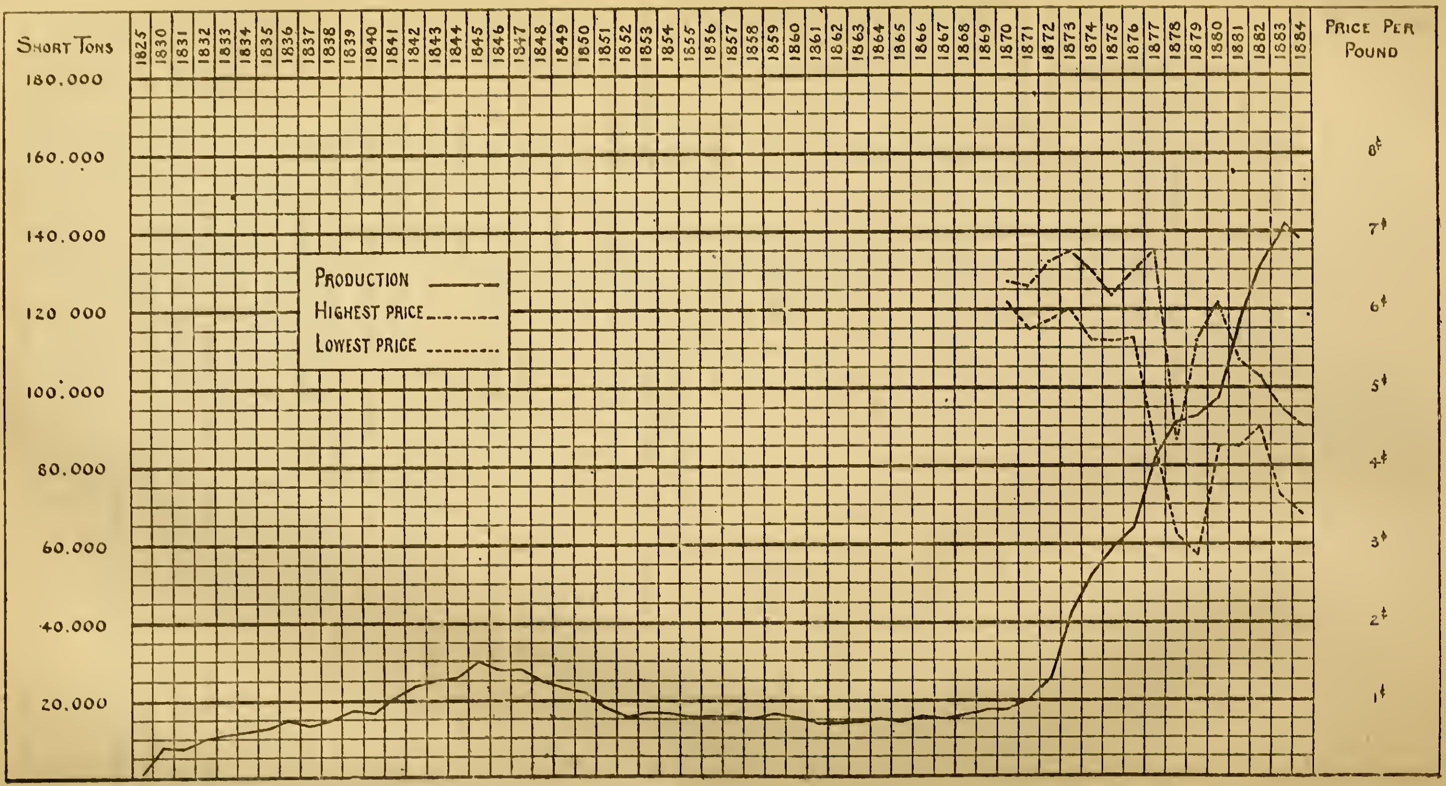

FIG. 4.—PRODUCTION OF LEAD IN THE UNITED STATES, 1825 TO 1884 INCLUSIVE, AND PRICE SINCE 1870.

The returns for desilverized lead include the official statement of every refining company in the country, with the exception of the Castle Dome works, which has been estimated.

An effort has been made to trace the source of the lead produced in the United States, in order thus to obtain some clew to the comparative importance of the different States and Territories as producers of this metal. Such an inquiry is beset with a great many difficulties, due to the active interchange between the different political divisions of the West. Ore goes from one State or Territory to another, and its lead contents appear in the returns of the State in which the smelter is located by which it was treated. A majority of the refining and desilverizing works smelt ores also, often buying them through sampling works, so that they are ignorant of the source from which they came. Some of these works refine only a part of the base bullion obtained in their own smelting works, shipping the balance to other refiners. The lead thus loses its identity and the returns of refiners and smelters, the preparation of which alone requires much labor, must be thoroughly examined. These returns have been kindly furnished by the different refining works and by many of the large smelting works known to handle more than simply local ores. But even with all the data at hand, only an estimate can be submitted, absolute accuracy being unattainable. The following figures are the results of the investigation:

Source of the lead produced in the United States in 1883 *and* 1884, *by States and Territories.*

States and Territories.	1883.	1884.
	Short tons.	*Short tons.*
Utah	29, 000	28, 000
Nevada	6, 000	4, 000
Colorado	70, 557	63, 165
Montana	5, 000	7, 000
Idaho	6, 000	7, 500
New Mexico	2, 400	6, 000
Arizona	1, 500	2, 700
California	1, 700	1, 600
Missouri, Kansas, Illinois, and Wisconsin	21, 600	19, 676
Virginia	200	256
Total	143, 957	139, 897

LEAD-PRODUCING REGIONS OF THE UNITED STATES.

Utah.—The production of the Territory has fallen off a little during 1884. The output since 1871 has been estimated as follows:

Production of lead in Utah.

Years.	Short tons.	Years.	Short tons.
1871	5, 000	1878	21, 000
1872	8, 000	1879	14, 000
1873	15, 000	1880	15, 000
1874	20, 000	1881	24, 000
1875	19, 000	1882	30, 000
1876	25, 000	1883	29, 000
1877	27, 000	1884	28, 000

The Horn Silver mine has remained the leading producer in the Territory during the years 1883 and 1884, though its make of base bullion fell off during the latter year to 11,700 short tons. The mine is expected to show a further sharp decline during the current year unless new reserves of lead ore are opened out. A large proportion of the balance of the lead ore mined in Utah has come from the Bingham district, whose shipments during 1884 are estimated to have aggregated fully 25,000 short tons, containing roughly between 9,000 and 10,000 tons of lead. The leading producers are the Brooklyn and the Lead mines, turning out together considerably more than half of the lead; the Yosemite, Spanish, Old Telegraph, and others being among the mines with a smaller output. In the Tintic district the Eureka has shipped fully 15,000 tons of low-grade ore, chiefly to Colorado smelters; the Peck, Bullion, Champion, and others contributing smaller quantities. The Black Dragon in the same district has supplied the smelters with the bulk of the iron flux required. In the Big Cottonwood district the Maxfield was the leading mine in point of output. The Utah ores are as a rule low in grade, but special efforts have been and are being made to concentrate them.

The report of the Horn Silver Mining Company is of particular interest, because it is the only company, with the exception of the Richmond Company, of Eureka, which converts the ores mined into finished marketable products—refined lead and bar silver. It furnishes some interesting figures, notably as to the cost of smelting and refining. There were smelted in 1883, as the produce of the mine, at the Francklyn furnaces 42,663 tons of ore, at a cost of $13.403 per ton against $14.73 in 1882, a reduction due partly to cheaper fuel since the completion of the Denver and Rio Grande railroad, and partly to the working of larger quantities. The average assay of the ore smelted was 36.83 per cent. of lead in 1883 against 37.8 per cent. in 1882, and 27.15 ounces of silver in 1883 against 34.2 ounces of silver in 1882. The cost of desilverizing and refining at Chicago 15,374 tons of base bullion produced was $7.95 in 1883 against $9.05 in 1882. From lead sales the company realized $1,193,320.61, from silver sales $1,324,651.63, and from interest account $33,824.87, a total of $2,551,807.11; and paid dividends earned aggregating $1,100,000; so that the silver nearly paid for the entire cost of extraction, treatment, general expenses, and marketing. The company has recently issued a circular to its shareholders announcing that the developments in the lower levels have thus far not proved satisfactory, and suspending dividends for the present. In 1884 the mine produced 40,000 tons of ore, averaging 30.9 per cent. of lead and 39 ounces of silver, the cost, delivered on cars, per ton of ore being $5.07. The cost of smelting rose to $14.24, the total cost per ton of base bullion, carrying 123.89 ounces of silver, being $18.43. The receipts were $707,205.02 for lead, $1,739,225.11 for silver, and $3,924.41 for sundries, a total of $2,450,354.54; while the operating expenses, including construction account, were $1,447,208.90. Coke costs $16 per ton, and freights on bullion to Missouri river points are $18 per ton.

Nevada.—Since 1877 the product of lead of the State has been as follows:

Production of lead in Nevada since 1877.

Years.	Short tons.	Years.	Short tons.
1877	19,724	1881	12,826
1878	31,063	1882	8,590
1879	22,805	1883	6,000
1880	16,659	1884	4,000

The only district of importance, furnishing almost the entire product, is the Eureka, in which the Eureka Consolidated and the Richmond companies are the principal producers. The following data, taken from the last annual reports of these companies, will furnish some idea of the conditions affecting the district generally:

According to the annual report of the Eureka Consolidated Mining Company for the year ending October 12, 1884, the company worked in its furnaces 14,144 tons of ore, of which 3,295 tons were custom ore, purchased for $117,394.50. It produced 1,397 tons of bullion, at a cost for smelting of $14.29 per ton of ore and $138.20 per ton of bullion, and paid about $59.37 per ton of bullion for freight and refining charges. With a greater product these figures would of course be somewhat reduced, but they indicate clearly that, as compared with other producing districts in the far West, Eureka is pretty heavily handicapped by high freights and cost of refining. The cost of smelting per ton of bullion is high because the ore smelted contains only about 10 per cent. of lead. The company levied during the year two assessments, aggregating $100,000.

The last annual report of the Richmond Company, for the fiscal year 1883, shows the product of 9,849 tons of Richmond ore and 9,762 tons of purchased ores to have been 3,256 tons of lead, 479,064 ounces of silver, and 14,750 ounces of gold, the total net profit being £30,146, of which £27,000 was paid in dividends. The cost of mining was $15.83 and the cost of smelting $11.72 per ton of ore. At the close of the fiscal year the company had on hand 8,449 tons of lead. During the first six months of the fiscal year 1884, carrying it up to the beginning of September, the company worked 12,081 tons of ore, producing 1,129 tons of lead, 183,709 ounces of silver, and 6,446 ounces of gold. Its stock of lead on January 1, 1885, was therefore probably nearly 11,000 tons.

Both of the companies have during the past years begun to work over the speiss rejected during a former period of prosperity, using new processes for which advantages are claimed. Both of them have a good deal of ground as yet not thoroughly prospected, so that the district may at any time become once more an important factor in the lead trade.

There is a prospect that the product of lead in Nevada will be increased slightly during the present year, as several small smelters in Esmeralda county have been started, and preparations are now in progress and well advanced for working the argentiferous lead ores of Spruce Mountain district, in the eastern part of the State.

Colorado.—This State has remained the heaviest contributor to the supply of lead of this country.

Production of lead in Colorado.

Years.	Short tons.	Years.	Short tons.
1873	56	1879	23, 674
1874	312	1880	35, 674
1875	818	1881	40, 547
1876	667	1882	55, 000
1877	897	1883	70, 557
1878	6, 369	1884	63, 165

Leadville, as the following figures show, has continued to furnish the bulk of the lead. For the years 1883 and 1884 the amounts of ore shipped and their lead contents are not known, but they continue to form the basis of the valley smelters, with the exception possibly of one.

Leadville bullion product.

Years.	Tons lead.	Ounces silver.	Ounces gold.	Tons of ore.	Value of ore shipments.
1877	175	376, 827	3, 750	3, 300	$400, 000
1878	2, 324	450, 476	897	15, 840	2, 360, 503
1879	17, 650	6, 004, 416	1, 100	18, 549	2, 851, 850
1880	33, 551	8, 999, 399	1, 687	12, 410	1, 460, 363
1881	38, 101	7, 102, 909	12, 192	15, 630	1, 016, 044
1882	39, 864	8, 376, 802	12, 615	22, 416	1, 872, 604
1883	36, 870	5, 057, 990	22, 330	(?)	6, 420, 692
1884	35, 296	5, 720, 904	22, 626	(?)	(?)

The output of the Leadville smelters, it will be observed, has fallen off during the years 1883 and 1884. Unfortunately the lead contents of the ores shipped are not known, and it is not possible to speak with certainty on the question whether the actual lead produce of the mines of the district has or has not seriously declined.

A question which has been agitating some of the mine owners in Leadville considerably, and has been the subject of some study on the part of smelters, has been the working of a class of ores which have been opened out in some mines. They are mixtures of iron pyrites, zincblende, and galena, carrying varying quantities of silver. The appearance of these undecomposed ores has been pointed to by some as the first sign of the decline of Leadville's greatness as a lead-producing camp, it being claimed that in other parts of the district deeper mining would undoubtedly reveal similar changes. It should not be forgotten, however, that the dropping out of the list of the heavy older producers is compensated for by the entering of new ones. There has been a good deal of speculation concerning the near future of Leadville from a lead-producing point of view. It is as urgently stated and as confidently denied that the yield of the metal will fall off. A calm survey of the field would, however, make it seem probable that so far as the immediate future is concerned heavy supplies are available, though not, of course, from the same sources.

It is certain, however, that the smelters, who are wholly or partially dependent upon Leadville ores as a supply of raw materials, will be forced—as indeed many of them have already been—to provide roasting facilities to treat the unoxidized ores. The general practice thus far has been to do the roasting in stalls, but it has been found that these are not efficient enough, and reverberatory furnaces have been introduced in at least one smelting establishment. The principal producers of this class of ore have been the Minnie Moore and the Colonel Sellers mines. A lot of several thousand tons of the ore from the latter mine contained on an average a little over 26 per cent. of lead, over 21 per cent. of zinc, and about 45 ounces of silver. Even after stall roasting little more than 5 per cent. of the total charge can be added of this class of ore, though reverberatory roasting permits of increasing the quantity to above 10 per cent. The stall roasting in reality converts only the iron pyrites into oxide, and it does not accomplish the principal aim of bringing the sulphide of zinc to the state of oxide. Though cheaper, it is in the end more expensive than reverberatory roasting, and the latter will become generally necessary if larger quantities of ore containing zinc as blende are to be treated. The cost of treatment and the losses are heavy, the latter being estimated at 10 to 12 per cent. on the silver and 15 per cent. on the lead. The charges are adjusted on a varying basis. They range between $21 and $22, with a deduction of a given percentage from the silver contents, and from 25 to 50 cents per unit for zinc above a minimum varying between 8 and 12 per cent., while the lead is generally paid for on a sliding scale ranging from 15 to 25 cents per unit. In the aggregate these deductions are very heavy, but so long as the silver contents range as high and higher than the example quoted, a fair margin remains for the miner. Large deposits are known to exist, however, in the Iron Silver mine for instance, which are lower in grade, and cannot be marketed at present charges and deductions for losses and excess of zinc. In silver this ore ranges between 11 and 14 ounces; in lead, between 15 and 44 per cent.; in zinc from 13 to 24 per cent.; in iron, from 11 to 16 per cent., and in sulphur from 30 to 40 per cent. It is pronounced to be suitable for concentrating, though the silver is fairly evenly distributed in the galena, blende, and pyrites. No steps have, however, been taken as yet to experiment with this material on a working scale. If fair prices could be realized for the blende this ore could be made available. Unless this question is solved, however, the Iron Silver, which, in 1883, was the heaviest lead producer in Leadville, will fall, in 1885, to a comparatively low rank. Its annual report shows some interesting figures. The total ore product was 92,271 tons of ore, dry weight, the average moisture having been 12.25 per cent. This ore contained 22,712 tons of lead and 1,405,176 ounces of silver, or an average of 24.6 per cent. of lead and 15.23 ounces of silver, for which was realized $1,484,936.04, leaving a profit of $425,674.23. Some of the ore was mined by tributers; that extracted by the company realized $16.01 per ton, the cost of production being $11.51, leaving, therefore, a profit of $4.50 per ton. The cost of mining proper was $9.06, the heaviest item being the labor account of $6.03. Improvements and developments called for $1.51 per ton, and general expenses for 94 cents. The figures for 1884 have not yet been published, but it is known that the lead product of the mine has fallen off considerably.

The next largest producer of lead is the Silver Cord Combination Mining Company, whose annual report for the fiscal year 1883 contained the following statement by the manager, Mr. T. S. Wood: The mine produced 30,084 tons of ore, or deducting the average of moisture, 13 per cent., 26,179 tons net, containing 6,104 tons of lead, 361,051 ounces of silver, and 8.084 ounces of gold, for which the smelters returned $496,973.33, their charges being $217,769.09, or $8.32 per ton. The working expense was $280,714.87, and $30,005.87 was spent on improvements, leaving a net profit of $186,252.89, or 26.12 per cent. of the value of the output.

While the appearance of sulphide ores on the one hand and the decline in the output of the largest lead producer are grave questions affecting the future, they are not looked upon as likely to have an immediate effect. One point is not generally understood, and should be particularly insisted upon. The lead product of the Leadville district is now more largely regulated by the demands on the part of the smelters for lead ores for fluxing purposes than by the price of the metal in the market. Thus it has happened that the prices paid per unit for lead in ores has advanced, while the New York market of that metal was declining. The smelters must have lead to smelt the dry silver ores, and will get it as long as the silver in the dry ores is able to pay for it. Therefore, if lead falls so low in the markets that certain mines cannot be profitably worked for the lead they contain, the ores rich in silver but poor in lead will be called upon to suffer a reduction in the prices paid for their ore. The figures which are obtained for lead ores vary according to the demand and supply, the character of the ore, whether they are siliceous or contain an excess of oxide of iron. While 25 cents is paid per unit for 20 per cent. ore, the smelting charge being $9, it goes as high as 40 to 45 cents per unit for 40 per cent. ore, while the smelting charge is only $6.50, and in some cases even under $6. It is estimated that in 1884 nearly 90 per cent. of the output of Leadville was oxidized ores, the balance being sulphuret ore.

The cost of fuel in Leadville has been reduced very little during the past two years, the current figure for coke being $13 per ton. The cost of smelting has therefore declined but little, and is said to range between $8.50 and $9.

One of the new camps which is beginning to attract attention, and which promises to become more prominent, is Aspen, where the Aspen Smelting Company started its first furnace in July, 1884, and is now building a second. The ores, taken from deposits at or near the contact of dolomite and Silurian limestone, carry fair quantities of lead, considerable zinc, some copper, and heavy spar as a chief constituent of the gangue, and are exceptionally high in silver. The district is favored by the existence of a 6-foot bed of good bituminous coal, making a good coke carrying only 10 per cent. of ash; and by the exercise of metallurgical skill, a constant watching of the character of the ores and of the working of the furnace, it has been possible, by running hot, to overcome the technical difficulties due to the presence of exceptionally large quantities of baryta and zinc. On the other hand the transportation to railroad is costly, though this is counterbalanced by the exceptionally high silver value of the bullion, which carries from 500 to over 1,000 ounces of silver per ton.

The mines of Red Cliff, in Eagle county, tributary to Leadville, are estimated to have shipped ores the lead contents of which foot up to about 3,300 tons, the prominent mines being the Belden, Eagle Bird, and Black Iron.

In the San Juan district the local smelting works have not, generally speaking, proved a success, and attention has been directed largely to concentrating the ores previous to shipment. The ores are frequently complex and refractory, but the quantity of lead coming from the district is in the aggregate considerable.

One new mine in Colorado, the Madonna, has furnished considerable lead during the years 1883 and 1884. It is owned by the Colorado Smelting Company of South Pueblo, and places that enterprise in the favorable condition of having a steady supply of ore high in lead not subject to the competition for this class of ores. The Madonna ore, however, carries little silver, and its utilization furnishes a striking example of the tendency already noted to open out lead deposits in spite of their low silver contents.

Montana.—The output of lead in Montana has increased somewhat during the years 1883 and 1884, and may be placed at 5,000 and 7,000 tons respectively. At present the leading lead mining camp is that in the vicinity of Helena, on which Mr. Waldemar Lindgren furnishes the following notes. The system of metalliferous veins is closely connected with a contact of granite and a probably Cretaceous or Tertiary liparitic rock, but is decidedly younger than both eruptions, cutting them both. The veins, always true fissures, are from 1 to 10 feet wide and carry, in a gangue of quartz, galena, zincblende, copper and iron pyrites, and mispickel, ruby or native silver being very rare. The galena carries up to 80 to 90 ounces of silver, the blende generally 10 to 12 ounces of silver, the fine pyrites from 0.2 to 0.3 ounces of gold and very little silver, while the copper pyrites seems to carry more silver, and the mispickel generally 1 ounce of gold. In some of the mines the blende occurs in comparatively large quantities.

The principal producers are the Helena Mining and Reduction Company, at Wickes (formerly the Alta Montana), and the Gregory Consolidated Company. The former has been thoroughly reorganized, and during the year 1884 produced 3,419 tons of lead, 4,606 ounces of gold, 620,950 ounces of silver, and 72,491 pounds of copper, paying in dividends $36,000 towards the end of the year, after a comparatively short period of building and remodeling of plant. According to the annual report covering the period up to November 1, 1884, the cost of mining at the Alta mine on 12,938 tons of ore was $5.10 per ton; at the Comet mine, $3.78 on 20,887 tons; while the cost of concentration at the mill of the former mine was $1.41 per ton, and at the latter $1.24. The cost of reduction of 8,003 tons of ore and concentrates was $16.25 for roasting and smelting, the plant consisting of eight roasting furnaces and two blast furnaces, with an estimated daily capacity of 75 tons, the fuel being chiefly charcoal. The iron ore for fluxing is obtained with some difficulty, the majority of the iron ore deposits in the vicinity being too siliceous. The Gregory Company has five reverberatory roasting furnaces and a smelting furnace, running intermittently, which produces from 5 to 6 tons of lead per day. In roasting charcoal is mixed in with the charge, the fuel being wood. The ore carries considerable zinc, material running as high as 15 per cent. zinc having been smelted.

The problem of the most economical and efficient treatment of these ores appears to have approached a solution, and a somewhat larger and steadier supply of base bullion may be looked forward to from that quarter. Districts similar in many respects, so far as the character of the ore deposits is concerned, which have attracted some attention recently, are the Red Mountain and Ten Mile, southwest of Helena. They are spoken of as certainly containing many excellent prospects, the development of which has been retarded by difficulties of transportation. A concentrating plant is now being erected in the Ten Mile Creek valley below the mines, all of which are located very high on the mountains.

In southern Montana the lead smelting center is Glendale, where the works of the Hecla Consolidated Mining Company are located. According to the annual report for 1883 the works treated 11,638 tons of ore, 540 tons of roast and 1,293 tons of matte, and produced 2,602 tons of lead, 599,472 ounces of silver, and 402 ounces of gold, together with matte containing 63,362 ounces of silver, and 308,519 pounds of copper, at a gross profit of $685,396.83, out of which dividends aggregating $360,000 were paid. In 1884 the smelters, to which a new stack had been added, worked 9,210 tons of ore, with 5,891 tons of iron ore, 2,800 tons of limestone, and 5,508 tons of slag, using as fuel 827,894 bushels of charcoal and 958,850 pounds of coke, at a cost of fuel per ton of charge of mixture of $5.05. The product was 2,295 tons of lead, 339,925 pounds of copper, 656,849.52 ounces of silver, and 248.264 ounces of gold, which yielded a gross profit of $241,743.35.

In northern Montana there is a smelting furnace at Clendenin, in the Barker district, which has not produced as much in 1884 as in 1883, while the plant of the Great Republic Company at Cooke City has run only at intervals, without turning out any notable quantities of base bullion. There are smelters also at Maiden and at Argenta, in Beaverhead county.

The output of base bullion of the Gregory, Helena, Hecla, and Clendenin works in 1883 aggregated 7,636 tons, and rose in 1884 to 12,331 tons. From the desilverizers' returns it appears that only a part of this product reached the refining works, the balance probably being still at the smelters or in transit.

Idaho.—During 1883 and 1884 Idaho has not, from a variety of causes, developed as a lead producer as rapidly as was expected in many quarters. The principal reason was, probably, that operations were limited in character, pending the completion of the branch of the Oregon Short Line railroad into the Wood River country. Still, the shipments have been on a fair scale, and the lead contents of the ores and bullion which have reached the market during the season of 1884 are estimated at about 7,500 tons. The country in which the ore-bearing zones have been developed is stated to consist of alternate beds of limestone and quartzite, the stratification of which is little disturbed by faults. The ore deposits themselves, limited to the limestone belts, are irregular, nor do they appear to conform in dip or strike with the limestone. The ore is principally galena, carrying fair quantities of silver; the principal gangue not closely mixed with the ore-bearing limestone. The ore is admirably adapted to cheap dressing, and a considerable number of concentrating plants have been put up during the past two years. The leading mines thus equipped are the Minnie Moore, the Eureka, Idahoan, Bullion, Queen of the Hills, Buzzo, Parker, Ontario, and others, some of which have already sent considerable ore to local or other smelters. Among other shipping mines the Viola, at Nicholia, the Elkhorn, Mayflower, O. K., and others may be mentioned. Other concerns like the Senate have been accumulating ores for future reduction. There are a considerable number of smelting plants, the largest being that of the Philadelphia Company, at Ketchum.

The district is favored, as compared with Colorado camps, by having a $25 railroad rate on bullion to Omaha and Missouri points, the local smelting charges being from $18 to $20, $25 deduction for freight to Omaha, the current freight from there to New York, the lead being paid for at New York rates, deducting 10 per cent. for loss, and the silver at New York figures, deducting 5 per cent. Unless the mining cost is carried too high by the possible necessity for heavy amounts of prospecting work, due to the irregularity of the deposits, the Wood River districts, with cheap concentrating, ranging from 50 cents to $1 per ton, and comparatively low freight rates, with a good grade of silver, should become large and profitable producers of lead at current rates and do much toward filling the decline which threatens to occur in the production of the metal in other quarters.

In 1883 the shipments of base bullion from the Wood River region were almost double the quantity of those of 1884. On the other hand, the ore shipments in the latter year were fully 10,000 tons. A conservative estimate made from the returns of the Union Pacific Railroad Company shows that the lead product in bullion and ore was 6,000 tons in 1883 and 7,500 tons in 1884. Of the latter, 6,650 tons are returned by refiners, leaving about 850 tons to swell the product of Utah and Colorado.

New Mexico.—In New Mexico the bulk of the lead produced has been turned out at the works of G. Billing, at Socorro, the basis of the enterprise being the ore from the Kelly mine, which is low in silver but high in lead, other ores being purchased. It is reported that the cost of smelting in this locality is lower than at any point in the far West. The product of the Territory is estimated at 2,400 tons in 1883, and at 6,000 tons in 1884, which latter figure in all probability will be maintained for the present, if it is not materially increased.

Arizona.—Thus far the lead product of Arizona has been small, and is practically confined to the operations of the smelting works at Benson, Cochise county, and a small quantity produced at Tombstone. The Howell works, which turned out considerable bullion in 1883, have been closed. The Benson works have not run continuously. They rely upon a lead ore low in silver as the basis of their operations, and have made a fair profit when working. The smelter of the Tombstone Mill and Mining Company was built to work the concentrates of tailings, which carry lead, heavy ores being purchased in addition. A fair quantity of Arizona lead ores goes to smelters in Colorado and to refining works.

Missouri, Kansas, Illinois, and Wisconsin.—A further decline has taken place in the yield of the non-argentiferous lead districts of these States. In 1883 the output of the Saint Joseph Lead Company, at Bonne Terre, Missouri, had suffered from the destruction of its works by fire, but in 1884 it again rose, and during the current year a further increase, which will carry it beyond a quota of 50 per cent. of the whole output of these States, is expected. Mine la Motte will probably hold its own this year, the mines looking as well as in 1884.

In Wisconsin the greater activity in mining, caused by a local market for the zinc ore, has led to an increase in the product of galena, the bulk of which is sold to desilverizing works for special purposes. Some ore from other districts is also disposed of in the same way.

In Illinois lead mining has almost entirely ceased, only very small quantities being raised.

Messrs. John Wahl & Co., of Saint Louis, estimate the output as follows for 1883 and 1884:

Districts.	1883.	1884.
	Short tons.	*Short tons.*
Southeast Missouri	11, 693	14, 979
Southwest Missouri and Kansas	7, 644	2, 437
Total	19, 337	17, 416

Messrs. Stone & Gove, of Galena, Kansas, have compiled some interesting figures in regard to the production of lead ore of that section, estimating its lead contents at 3,619 tons for 1884. Messrs. Wahl & Co.'s figure is therefore evidently too low, and there must be counted in addition 697 tons of lead from Kansas, Wisconsin, Illinois, and Missouri ores purchased by refiners. We therefore estimate the total production of non-argentiferous lead at 19,676 tons.

The Kansas district has rapidly decreased in the past two years in the production of lead ore, because the rich surface pockets within the depth of 30 to 70 feet have been worked out, and particularly because attention has been attracted to zinc mining.

The following table gives the yield since the year 1873, according to the estimates of Mr. E. A. Caswell, with the exception of the year 1874:

Production of non-argentiferous lead in Missouri, Kansas, Illinois, and Wisconsin.

Years.	Southwest district.	Galena district.	Total.
	Short tons.	*Short tons.*	*Short tons.*
1873	15, 045	7, 336	22, 381
1875	19, 099	5, 600	24, 699
1876	19, 225	7, 196	26, 421
1877	24, 734	6, 418	31, 152
1878	22, 278	4, 492	26, 770
1879	25, 330	2, 800	28, 130
1880			27, 690
1881			30, 770
1882			29, 015
1883			21, 600
1884			19, 676

Mr. F. de Stwolinski has furnished the following data on the lead and zinc region of southwest Missouri, embracing all the counties forming the southwestern corner of Missouri, or McDonald, Newton, Jasper, Dade, Lawrence, and Barry counties, and the southeastern corner of Kansas, in Cherokee county. The ore occurs in the sub-Carboniferous limestones, very irregularly distributed. At Joplin, the center of the district, the Atlantic, the Pacific, and the Florence mining companies are at work on lands belonging to the Picher Lead and Zinc Company. Other parties working in the district are the Lone Elm Mining Company, Guinn & Lloyd, Haskell, Hicks & Ditman, Ontario Mining Company, and Lucas and Collins on the Paxton lands. South of Joplin there are a number of mines in operation, among which those of E. B. Leonards, at Roaring Spring, and the Leckie mines at Gordon Hollow are prominent. Twelve miles south of Joplin the Spurgeon mines are being opened up with good prospects of success, while the Mosley mines near by are being reopened. Four miles east of Joplin are the Dillville mines, operated by the Hammett Lead and Zinc Company, and the old Burch mines, worked by Pennsylvania parties.

At the Short Creek mines in Cherokee county, Kansas, 7 miles west of Joplin, J. Murphy is operating mines and two concentrators; the Galena Zinc Company, a crusher and concentrator; Boyce, a crusher and concentrator; Cody, a custom works; S. L. Cheeny, a concentrator; Southside Mining and Smelting Company, a smelter; and the Excelsior Crusher Company, a crusher and separating works. At Stanley, 2 miles northwest of this point, Schermerhorn & Tamblye are mining, and there is also located there the O'Neil crusher. The Granby Mining and Smelting Company has a smelter and concentrator and are working also at Oronogo, 7 miles north, and at Granby, 20 miles southwest. Two miles north of Joplin work is being done by Lee Taylor and the Sterling Lead and Zinc Company; while 4 miles north of Joplin the West Joplin Lead and Zinc Company is mining at the Sherwood diggings. Lehigh City, about 7 miles northwest of Joplin, is the scene of considerable activity, and a large number of mines are being worked at Webb City and at Carterville.

REFINING AND DESILVERIZING WORKS.

The desilverizing and refining of argentiferous base bullion has grown to a business of great magnitude, which is now conducted with a skill and on a scale not equaled elsewhere. The following works are actively engaged in the business: Selby Smelting and Lead Company, San Francisco, California; Richmond Mining Company of Nevada, Eureka, Nevada; Germania Lead Works, Salt Lake City, Utah; Pueblo Smelting and Refining Company, Pueblo, Colorado; Omaha and Grant Smelting and Refining Company, Omaha, Nebraska; Kansas City Smelting and Refining Company, Argentine, Kansas; Aurora Smelting and Refining Company, Aurora, Illinois; Saint Louis Smelting and Refining Company, Saint Louis, Missouri; Chicago Smelting and Refining Company, Chicago, Illinois; Horn Silver Mining Company, Chicago, Illinois; Pennsylvania Lead Company, Mansfield Valley P. O., Pennsylvania, and Newark Smelting and Refining Works (Edward Balbach & Son), Newark, New Jersey. The Castle Dome Works, the Delaware Lead Works, and the Manhattan Smelting and Refining Company have not done any work for some time.

REVIEW OF THE LEAD MARKET.

The following table gives the highest and lowest prices monthly for a series of years:

Highest and lowest prices of lead at New York City, monthly, from 1870 *to* 1884 *inclusive.*

[Cents per pound.]

Years.	January.		February.		March.		April.		May.		June.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1870	*a*6.30	6.20	6.25	6.17	6.20	6.10	6.25	6.15	6.25	6.20	6.25	6.20
1871	*a*6.30	6.15	6.25	6.20	6.20	6.15	6.20	6.10	6.18	6.10	6.15	6.12
1872	*a*6.00	5.90	6.00	5.87	6.00	5.87	6.12	5.90	6.62	6.25	6.62	6.40
1873	*a*6.37	6.25	6.50	6.40	6.50	6.25	6.50	6.25	6.62	6.35	6.55	6.12
1874	*a*6.00	5.90	6.25	6.00	6.25	6.12	6.25	5.90	6.00	5.75	6.00	5.62
1875	*a*6.20	6.00	5.90	5.85	5.75	5.62	5.87	5.80	5.95	5.90	5.90	5.75
1876	*a*6.00	5.87	6.37	6.00	6.50	6.40	6.40	6.12	6.50	6.10	6.50	6.25
1877	*b*6.15	6.12	6.40	6.20	6.75	6.50	6.50	6.25	6.00	5.55	5.70	5.60
1878	4.35	4.00	3.87	3.65	3.87	3.62	3.75	3.50	3.50	3.25	3.50	3.12
1879	4.50	4.00	4.50	4.50	4.50	3.25	3.25	2.87	3.12	2.87	3.80	3.12
1880	6.10	5.50	6.00	5.87	5.95	5.30	5.75	5.40	5.25	4.40	4.75	4.50
1881	5.00	4.30	5.10	4.80	4.85	4.62	4.85	4.37	4.70	4.25	4.50	4.25
1882	5.15	4.95	5.20	5.00	5.12	4.85	5.00	4.90	4.85	4.60	4.90	4.55
1883	4.70	4.60	4.60	4.50	4.65	4.50	4.62	4.40	4.55	4.40	4.45	4.40
1884	4.50	3.75	4.10	3.75	4.15	4.10	4.05	3.62½	3.75	3.52½	3.65	3.57½

Years.	July.		August.		September.		October.		November.		December.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1870	6.30	6.20	6.37	6.32	6.37	6.30	6.37	6.25	6.35	6.25	6.35	6.25
1871	6.15	6.10	6.12	6.00	6.10	6.00	6.00	5.87	6.00	5.90	6.00	5.75
1872	6.62	6.40	6.50	6.40	6.50	6.30	6.62	6.40	6.60	6.50	6.60	6.42
1873	6.12	6.00	6.25	6.00	6.62	6.37	6.75	6.25	6.50	6.00	6.12	6.00
1874	5.80	5.62	5.80	5.65	6.10	5.65	6.35	6.10	6.50	6.25	6.40	6.12
1875	6.00	5.95	5.95	5.87	5.87	5.70	5.65	5.60	5.87	5.65	5.95	5.87
1876	6.35	6.20	6.37	6.25	6.25	6.00	6.00	5.80	5.80	5.70	5.70	5.65
1877	5.60	5.37	5.12	4.90	4.85	4.75	4.85	4.25	4.75	4.50	4.60	4.50
1878	3.62	3.25	3.50	3.20	3.45	3.25	3.60	3.37	3.95	3.60	4.00	3.90
1879	4.10	3.90	4.05	4.00	4.00	3.75	5.50	4.00	5.62	5.00	5.60	5.50
1880	4.75	4.25	5.00	4.30	4.90	4.80	4.87	4.65	4.85	4.75	4.75	4.25
1881	4.90	4.50	4.95	4.75	5.37	4.95	5.25	4.87	5.25	4.90	5.25	5.00
1882	5.15	4.90	5.10	4.95	5.15	4.95	5.15	4.85	4.90	4.50	4.75	4.50
1883	4.40	4.30	4.30	4.20	4.32	4.30	4.32	4.12	4.05	3.65	3.75	3.60
1884	3.70	3.55	3.70	3.52½	3.75	3.55	3.75	3.60	3.55	3.37½	3.75	3.50

a Gold. *b* Currency.

An average of the sales reported in the *Engineering and Mining Journal* during the years 1883 and 1884 from week to week in the three principal markets, New York, Chicago, and Saint Louis, aggregating in 1883 50,250 tons, will yield a fair approximation to the figures at which lead has sold. The sales at Saint Louis and Chicago are of course converted into their equivalent laid down in New York.

Average market price of lead at New York city.

Periods.	Cents per pound.
First half, 1883	4.51
Second half, 1883	4.07
Average, 1883	4.28
First half, 1884	3.824
Second half, 1884	3.632
Average, 1884	3.766

These figures, of course, are the average, irrespective of different brands and qualities, and, as they do not include jobbing sales, represent very closely the average result of wholesale transactions. The differences between market prices of the different qualities of lead have become much smaller than they were formerly, and are rarely larger than 5 cents per hundred pounds, or $1 per ton.

1883.—During the year quotations have moved within the following monthly range:

Price of lead in 1883.

[Cents per pound.]

Months.	Highest.	Lowest.
January	4.75	4.65
February	4.62	4.50
March	4.70	4.45
April	4.65	4.40
May	4.45	4.40
June	4.45	4.40
July	4.40	4.30
August	4.30	4.20
September	4.32	4.30
October	4.32	4.12
November	4.05	3.65
December	3.75	3.60

Opening quietly, though with some firmness, notably in the West, until in the beginning of the month of March about 3,000 tons were taken, principally by the trade, an effort to depress prices being made later in the month by additional sales at lower prices. April passed quietly, while May opened with the placing of about 3,000 tons among consumers on the part of the representatives of two large works. Buyers were thus tolerably well supplied, especially as the demand for manufactures during the first quarter of the year was very light. Under the impression that stocks were accumulating, buyers held off persistently in the beginning of July and the market weakened. Holders during the entire month maintained a firm attitude, and though they made every effort to stay a decline, the tone remained unfavorable. In August there was practically a deadlock, relieved only during the close of the month by a tendency on the part of western holders to pick up odd lots. In the second week of September there was greater activity, but it showed clearly that the market swerved promptly under any attempts to market larger quantities of lead. The fact was generally understood and appreciated that the market was artificially sustained; that there was no scarcity of the metal, and that on the contrary the load which holders were carrying was growing steadily day by day. Buyers did not therefore depart from their waiting position, and the market continued dull. In the beginning of October an offer of 4 cents for the stock of 2,000 tons of Richmond lead was declined, and later a decline was brought about by the forcing of some lots. Thus the deadlock continued until November, which opened with large sales at a decline to 4 cents, followed a week afterward by another plunge downward to 3.75 cents. Some other large sales, partly speculative were made at 3.70 cents and the month closed dull with the metal at 3.65 cents. December was very uneventful, and it was only towards the end of the year that holders again showed a tendency to stiffen.

1884.—During 1884 the price of lead fluctuated as follows from month to month:

Price of lead in 1884.

[Cents per pound.]

Months.	Highest.	Lowest.
January	4.50	3.75
February	4.10	3.75
March	4.15	4.10
April	4.05	3.62½
May	3.75	3.52½
June	3.65	3.57½
July	3.70	3.55
August	3.70	3.52½
September	3.75	3.55
October	3.75	3.60
November	3.55	3.37½
December	3.75	3.50

The year started with an advance by holders to 4 cents, and after 1,200 tons had been taken off the hands of the holders by a western firm, consumers followed suit, taking about 800 tons at the range of 4.22 to 4.25 cents, when the asking price was promptly raised to 4⅜ cents. The ostensible reason for this advance was the restriction of the output in the West due to the obstruction of transportation by snowfalls. It brought out offers of Spanish lead at 4.50 cents, though the advance here reacting upon Europe soon ran the limits above that figure. It became known afterwards, too, that the western corroders had entered into an agreement not to go into the market, and suddenly the purchaser of large blocks early in the month became a free seller, and in a few days over 2,000 tons of lead were sold, the bulk at 4 cents, and at the end of the month lead was freely offered from the West at 3.75 cents without tempting buyers, who were frightened by the erratic movements of the metal in what is generally, so far as consumption is concerned, the dullest month in the year. February again witnessed considerable manipulation, a speculative purchase of 500 tons being made early in the month, followed by an advanced asking price to 4 cents. This was followed up by further buying by the same parties of about 1,500 tons at 4.10 cents, without, however, inducing consumers to take hold at once. They did, however, in March buy about 2,500 tons at 4.10 to 4.15, leaving the market in a dull, stagnant condition for the rest of the month. Early in April holders again weakened, parting with about 1,000 tons, the bulk of it at 4 cents. For a week or two the market remained dull, the Richmond Company declining an offer of 4⅛ cents for 10,000 tons, to be delivered in blocks of 1,000 tons per month. A pressure to sell became manifest, and suddenly the market gave way under sales of upward of 5,000 tons for June, July, and August delivery at 3.75, followed by the sale of odd lots at 3.62½ and 3.65. Consumers, being heavily stocked, were apathetic, and the greater part of May passed with small sales down to 3.52½. A meeting of the representatives of the refining works, held in Chicago on the 22d and 23d, led to no results whatever so far as any action looking toward a betterment of prices was concerned, though the market did temporarily stiffen to 3.75 cents. June passed by very quietly, the bulk of the sales being made at 3.57½ cents, while the highest point touched was 3.65 cents, and July showed only a temporary improvement toward the end, which was, however, lost in August, sellers being quite urgent, while buyers followed a waiting policy, which they clung to, in spite of the approach of the busy season, until the middle of September, when purchasers on their part advanced the metal to 3.75 cents. In October small speculative purchases were made, but the November product remained unsold and the market displayed a weakening tendency, which in the second week of November led to almost a panic in the metal. Starting with small sales at 3.55 cents, over 1,000 tons were disposed of to consumers at 3.50 cents, followed up by small parcels at 3.45 and 3.40 cents. The lowest point touched was 3.37½, and with the December product as yet unplaced, the outlook was unpromising, when it became known that a strike in the Colorado coal fields, threatening to cut off the supply of coke, temporarily created a better feeling. In the beginning of December the principal holder advanced his price to 3.50 cents, and soon afterward to 3.75 cents, but what little lead was wanted was apparently available at 3.60 cents, and the year closed with the market flat and dull. The year has in an exceptional degree been influenced by manipulation, which, it will be noticed, was not always successful. It did probably have the effect, however, of keeping values at a higher level than they might otherwise have been. Considering the general depression of business, and the heavy production, the consumption was certainly very large and gives encouragement to the belief that even a small decline in the output, or some improvement in general business, will carry values to a higher level.

IMPORTS.

The imports of foreign lead have fallen off to insignificant figures since our home mines developed with such marvelous rapidity. The following tables give in detail the quantities of ore and dross, pigs and bars, sheets, pipe, and shot, and other manufactures not specified, imimported since 1867:

Lead imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Ore and dross.		Pigs and bars.		Sheets, pipe, and shot.		Shot.		Not otherwise specified.	Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*			
1867	611	$25	65, 322, 923	$2, 812, 668	185, 825	$9, 560	....	....	$6, 222	$2, 828, 475
1868	6, 945	239	63, 254, 677	2, 668, 915	142, 137	7, 229	....	....	6, 604	2, 682, 987
1869	....	......	87, 865, 471	3, 653, 481	307, 424	15, 531	....	....	18, 885	3, 687, 897
1870	5, 973	176	85, 895, 724	3, 530, 837	141, 681	6, 879	....	....	10, 444	3, 548, 336
1871	316	10	91, 496, 715	3, 721, 096	86, 712	4, 209	....	....	8, 730	3, 734, 045
1872	32, 331	1, 425	73, 086, 657	2, 929, 623	12, 518	859	....	....	20, 191	2, 952, 098
1873	....	.....	72, 423, 641	3, 233, 011	105	12	420	$50	21, 503	3, 254, 576
1874	....	......	46, 205, 154	2, 231, 817	....	....	30, 219	1, 349	36, 484	2, 269, 650
1875	13, 206	320	32, 770, 712	1, 559, 017	....	....	58	4	25. 774	1, 585, 115
1876	....	......	14, 329, 366	682, 132	....	....	20, 007	1, 204	27, 106	710, 442
1877	1, 000	20	14, 583, 845	671, 482	....	....	16, 502	1, 242	1, 041	673, 785
1878	....	......	6, 717, 052	294, 233	....	....	15, 829	963	113	295, 309
1879	....	......	1, 216, 500	42, 983	....	....	3, 748	209	930	44, 122
1880	....	......	6, 723, 706	246, 015	....	....	1, 120	54	371	246, 440
1881	5, 981	97	4, 322, 068	189, 129	....	....	900	65	1, 443	160, 734
1882	21, 698	500	6, 079, 304	202, 603	....	....	1, 469	99	2, 449	205, 651
1883	600	17	4, 037, 867	130, 108	....	....	1, 510	79	8, 030	138, 234
1884	419	13	3, 072, 738	85, 395	15, 040	630	....	....	1, 992	88, 030

Old and scrap lead imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	1, 255, 233	$53, 202	1876	265, 860	$9, 534
1868	2, 465, 575	101, 586	1877	249, 645	8, 383
1869	2, 983, 272	123, 068	1878	106, 342	3, 756
1870	3, 756, 785	150, 379	1879	42, 283	1, 153
1871	2, 289, 688	94, 467	1880	213, 063	5, 262
1872	4, 257, 778	171, 324	1881	123, 018	2, 729
1873	3, 545, 098	151, 756	1882	220, 702	5, 949
1874	395, 516	13, 897	1883	1, 094, 133	31, 724
1875	382, 150	13, 964	1884	160, 356	4, 830

Lead ashes imported and entered for consumption in the United States, 1869 *to* 1881 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$1, 461	1875	$503
1870	8, 892	1876	4, 241
1871	8, 852	1877	33, 297
1872	1, 315	1878	4, 886
1873	254	1879	69
1874	1, 583	1881 (*a*)	67

a Not separately classified since 1881.

EXPORTS.

Except during the period of 1842 to 1846, both fiscal years included, and in the years 1878 and 1879, when considerable quantities of lead were sent to China, the export movement of lead has always been insignificant as compared with the home production.

Lead and manufactures of lead, of domestic production, exported from the United States.

Fiscal years ending September 30 until 1842, and June 30 since.	Manufactures of—			Bars, shot, etc.		Total value.
	Lead.		Pewter and lead.			
	Quantity.	Value.	Value.	Quantity.	Value.	
	Pounds.			*Pounds.*		
1790	13,440	$810				$810
1803 (barrels)	900					
1804	19,804					
1805	8,000					
1808	40,583					
1809	126,537					
1810	172,323					
1811	65,497					
1812	74,875					
1813	276,940					
1814	43,600					
1815	40,245					
1816	35,844					
1817	111,034	9,993				9,993
1818	281,168	22,493				22,493
1819	94,362	7,549				7,549
1820	25,699	1,799				1,799
1821	56,192	3,512				3,512
1822	66,316	4,244				4,244
1823	51,549	3,098				3,098
1824	18,604	1,356				1,356
1825	189,930	12,697				12,697
1826	47,337	3,347				3,347
1827	50,160	3,761				3,761
1828	76,882	4,184				4,184
1829	179,952	8,417				8,417
1830	128,417	4,831				4,831
1831	152,578	7,068				7,068
1832	72,439	4,483				4,483
1833	119,407	5,685				5,685
1834	13,480	805				805
1835	50,418	2,741				2,741
1836	34,600	2,218				2,218
1837	297,488	17,015				17,015
1838	375,231	21,747				21,747
1839	81,377	6,003				6,003
1840	882,620	39,687				39,687
1841	2,177,164	96,748				96,748
1842	14,552,357	523,428				523,428
1843 (nine months)	15,366,918	492,765				492,765
1844	18,420,407	595,238				595,238
1845	10,188,024	342,646				342,646
1846	16,823,766	614,518				614,518
1847	3,326,028	124,981				124,981
1848	1,994,704	84,278				84,278
1849	680,249	30,198				30,198
1850	261,123	12,797				12,797
1851			$16,426	229,448	$11,774	28,200
1852			18,469	747,930	32,725	51,194
1853			14,064	100,778	5,540	19,604
1854			16,478	404,247	26,874	43,352
1855			5,233	165,533	14,298	19,531
1856			5,628	510,029	27,512	33,140
1857			4,818	870,544	58,624	63,442
1858			27,327	900,607	48,119	75,446
1859			28,782	313,988	28,575	57,357
1860			56,081	903,468	50,446	106,527
1861			30,534	109,023	6,241	36,775
1862			28,832	79,231	7,334	36,166
1863			30,609	237,239	22,634	53,243
1864			30,411	223,752	18.718	49.129

Lead and manufactures of lead exported, &c.—Continued.

Fiscal years ending September 30 until 1842, and June 30 since.	Manufactures of—			Bars, shot, etc.		Total value.
	Lead.		Pewter and lead.			
	Quantity.	Value.	Value.	Quantity.	Value.	
	Pounds.			*Pounds.*		
1865	....	....	$29,271	852,895	$132,666	$161,937
1866	....	....	44,483	25,278	2,323	46,806
1867	....	....	27,559	99,158	5,300	32,859
1868	....	....	37,111	438,040	34,218	71,329
1869	....	....	17,249	....	....	17,249
1870	....	$28,315	....	....	....	28,315
1871	....	79,880	....	....	....	79,880
1872	....	48,132	....	....	....	48,132
1873	....	13,392	....	....	....	13,392
1874	....	302,044	....	....	....	302,044
1875	....	429,309	....	....	....	429,309
1876	....	102,726	....	....	....	102,726
1877	....	49,835	....	....	....	49,835
1878	....	314,904	....	....	....	314,904
1879	....	280,771	....	....	....	280,771
1880	....	49,899	....	....	....	49,899
1881	....	39,710	....	....	....	39,710
1882	....	178,779	....	....	....	178,779
1883	....	43,108	....	....	....	43,108
1884	....	135,156	....	....	....	135,156

THE PRINCIPAL FOREIGN PRODUCERS.

For many years the United States has been practically independent of foreign markets of lead, and the statistics of the foreign production possess only a general interest. They can affect our own makers only in two contingencies, barring a reduction of the duty—either by checking a rise above the importing point, which seems improbable in the near future, or by so serious a decline of values here that exports to foreign countries become possible, a case which seems almost as far removed.

The production of lead in the world has been estimated as follows:

The world's production of lead.

Countries.	1876.	1881.	1882.	1883.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
Spain	101,522	105,809	115.368	126,889
Germany	77,500	90,216	92,591	94,811
England	59,606	49,364	51,133	39,817
France	21,339	*a* 8,500	8,076	*a* 8,000
Italy	*a* 9,000	*a* 9,000	*a* 9,000	*a* 9,000
Greece	*a* 8,000	11,892	6,645	*a* 8,200
Belgium	7,275	7,651	8,805	8,391
Austria	4,291	8,783	11,113	11,134
Hungary	*a* 2,000	*a* 1,850	1,843	*a* 1,800
Russia	1,083	*a* 1,000	*a* 1,000	*a* 1,000
Sweden	*a* 400	*a* 400	494	*a* 500
United States	58,118	106,208	120,544	139,836
Mexico	*a* 1,000	*a* 1,000	*a* 1,000	*a* 1,000
Turkey	*a* 250	*a* 250	*a* 500	*a* 750
Australia	*a* 500	*a* 500	*a* 1,000	*a* 1,500
South America	....	....	*a* 1,500	*a* 2,000
Total	351,884	402,423	430,612	454,628

a Estimated.

Great Britain.—The tendency toward a decline in the output of the British mines has been more marked during 1883 than ever before. The figures for 1884 are not yet available, but the frequent reports of the closing down of mines, and the voluntary liquidation of mining companies, make it probable that the showing for 1884 will be even poorer. The following figures are gathered from the official statistics:

Lead statistics of Great Britain.

Years.	Production of lead ore.	Lead from British ores.	Silver.	Lead imported and obtained from foreign ores.	British and foreign lead exported.	Available for home consumption.
	Long tons.	*Long tons.*	*Ounces.*	*Long tons.*	*Long tons.*	*Long tons.*
1874	76, 801	58, 777	509, 277	74, 351	41, 321	91, 807
1875	77, 746	57, 435	487, 358	89, 705	38, 624	108, 516
1876	79, 096	58, 667	483, 422	91, 010	42, 685	106, 992
1877	80, 850	61, 403	497, 375	105, 472	47, 885	118, 990
1878	77, 350	58, 023	397, 471	112, 977	36, 478	134, 519
1879	66, 878	41, 635	333, 674	117, 014	40, 530	128, 119
1880	72, 245	56, 949	295, 518	107, 211	38, 344	125, 816
1881	64, 702	48, 587	308, 398	106, 593	48, 453	106, 727
1882	65, 001	50, 328	372, 446	100, 331	40, 018	110, 641
1883	50, 980	39, 190	344, 053	118, 521	42, 848	114, 863

The principal sources of the lead and lead ore imported into England are the following, the total for the year 1883 being 20,249 tons of lead ore, 101,715 tons of pig lead and sheet lead, and 15,780 cwts. of lead manufactures:

Imports of lead and lead ore into Great Britain in 1883.

Countries.	Ore.	Pig lead.
	Long tons.	*Long tons.*
Germany	47	3, 933
Holland	5	6, 556
Belgium	61	1, 251
France	2, 763	377
Spain	2, 906	80, 855
Italy	5, 386	....
Greece	....	6, 827
Turkey	1, 339	280
Algeria	1, 881	....
United States	50	1, 268
Peru	1, 416	....

English lead is shipped to all quarters of the globe, the following being the principal customers:

Exports of lead from Great Britain.

Countries.	1883.		1884.
	Pig lead.	Rolled pipe and sheet lead.	
	Long tons.	*Long tons.*	*Long tons.*
Russia	3, 480	2, 113	4, 494
France	1, 034	18	1, 061
British East Indies	1, 349	2, 546	4, 386
China	6, 158	214	6, 632
Hong-Kong	6, 242	345	
Australia	1, 664	4, 015	5, 210
Canada	1, 575	571	....
United States	1, 276	32	649
Brazil	968	638	....
Total	23, 746	10, 492	22, 432

The China market is therefore the most important of all to English exporters; next in magnitude being India and Russia.

Spain.—In spite of the constant decline of lead in the English market during 1883, the exports of that year eclipsed those of the preceding year. The returns for the first eight months of 1884 indicate, however, that the production has fallen off, the exports having been 75,596 metric tons for that period as compared with 83,325 tons during the corresponding time in 1883. Since 1878 the exports have been as follows:

Exports of lead from Spain.

Years.	Metric tons.
1878	90, 842
1879	100, 336
1880	92, 400
1881	105, 809
1882	115, 368
1883	127, 793

According to official figures for 1883, the exports were 51,898 tons of argentiferous base bullion, of which 31,420 tons went to England, and 20,477 tons to France, and 76,895 tons of desilverized lead, of which 50,702 tons were exported to England and 25,139 tons to France. The Spanish desilverizing industry has therefore succeeded in cutting down the exports of base bullion to less than one-third of the total make.

Germany.—The production of Germany, the second in importance in Europe, has been as follows for a series of years:

Production of lead in Germany.

Years.	Quantity.	Years.	Quantity.
	Metric tons.		*Metric tons.*
1852 to 1855	15, 000 to 20, 000	1875	69, 900
1856 to 1859	20, 000 to 25, 000	1876	77, 500
1860	28, 000	1877	79, 970
1861 and 1862	30, 000 to 35, 000	1878	83, 336
1863 and 1864	35, 000 to 40, 000	1879	85, 566
1865 and 1866	40, 000 to 45, 000	1880	88, 867
1867	49, 000	1881	90, 216
1868 to 1872	50, 000 to 60, 000	1882	95, 860
1873	64, 000	1883	94, 811
1874	72, 030		

The exports from and imports of lead into Germany have been as follows, for a series of years, in metric tons:

Exports and imports of lead from and to Germany.

Years.	Imports.	Exports.	Apparent home consumption.
	Metric tons.	*Metric tons.*	*Metric tons.*
1877	3, 031	31, 582	51, 419
1878	2, 999	44, 476	41, 859
1879	4, 284	43, 258	46, 692
1880	2, 615	45, 419	47, 063
1881	2, 661	46, 799	46, 078
1882	1, 973	41, 875	55, 958
1883	3, 165	49, 474	48, 502

The production of the different districts in Germany is shown by the following table, the make of silver being added, since it largely influences the profits of the different works. In the case of Freiberg and the Hartz it probably includes some silver extracted from rich imported Mexican and South American ores:

Production of lead and silver in Germany.

Districts.	Lead.			Silver.		
	1881.	1882.	1883.	1881.	1882.	1883.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Kilos.*	*Kilos.*	*Kilos.*
Prussia:						
Stolberg Company	13, 996	14, 919	13, 753	20, 227	26, 130	23, 989
Rhenish-Nassau Company	7, 200	6, 239	6, 457	6, 212	7, 608	5, 953
Mechernich Company	22, 409	25, 055	25, 582	4, 438	5, 108	4, 369
Commern Company	2, 362	2, 727	1, 640	1, 181	988	525
A. Poensgen & Sons	3, 189	3, 100	3, 540	1, 382	1, 175	1, 757
Rothenbach Works	55	40	44	969	901	886
Walther Cronek Works	5, 489	5, 858	5, 154	4, 056	3, 679	3, 397
Friedrichs Works	8, 450	8, 683	9, 561	5, 532	5, 245	5, 755
Hanover:						
Upper Hartz	9, 428	10, 447	9, 749	26, 385	32, 592	37, 259
Lower Hartz	424	579	599	3, 854	3, 575	5, 252
Nassau:						
Ems	5, 772	5, 803	5, 227	6, 887	7, 403	7, 418
Braubach	2, 721	3, 176	3, 187	5, 515	6, 085	9, 915
Saxony:						
Freiberg	4, 494	5, 064	5, 274	39, 133	50, 985	58, 946
Total	85, 989	91, 690	89, 767	125, 771	151, 474	165, 421

These figures do not include the litharge, added in the general table given on the preceding page.

The principal countries to which Germany ships lead may be traced by the following table:

Exports of lead from Germany.

Countries.	1880.	1881.	1882.	1883.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
Hamburg and Bremen	8, 491	6, 521	6, 583	6, 067
Russia	3, 344	4, 420	6, 142	9, 419
Austria-Hungary	2, 955	2, 094	376	1, 104
France	9, 055	14, 025	14, 539	14, 677
Belgium	7, 191	7, 530	5, 279	4, 056
Holland	5, 766	5, 694	3, 654	5, 103
Great Britain	6, 678	3, 613	3, 515	7, 935
Total	43, 480	43, 897	40, 088	48, 361

This table, in consequence of the fact that German exports are largely made through ports not in the empire, does not fully exhibit the movement. Thus the exports from Hamburg, which include all but a few hundred tons annually of the totals given above, show, when examined, the following, which is of special interest as making it able to trace how much Germany contributes to the China market.

Movement of lead through Hamburg.

Years.	Exports from Hamburg to—			Imports into Hamburg from England.
	England.	Russia.	China.	
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
1880	6,264	1,028	3,940	497
1881	2,980	298	4,850	535
1882	2,616	210	4,942	705
1883	2,829	182	3.223	449

The imports of English lead into Hamburg are probably merely in transit to China.

The shipments of lead to Belgium and Holland are largely in transit to France and England. Combining the export figures of Hamburg and of Germany, we reach the following figures as the totals of the exports of Germany, and their destination:

Total exports of lead from Germany, and destination.

Countries.	1882.	1883.	Countries.	1882.	1883.
	Metric tons.	*Metric tons.*		*Metric tons.*	*Metric tons.*
Russia	6,353	9,602	Holland	3,733	5,147
Austria-Hungary	376	1,104	Great Britain	6,131	10,764
France	14,539	14,677	China	4,942	3,223
Belgium	5,284	4,076	United States	356	151

The most interesting figure is that relating to China. Adding the exports of England to the same quarter, we reach the conclusion that from these two sources that country received in 1883 about 16,500 tons of lead.

Belgium.—The importance of Belgium as a producer of lead has declined very rapidly during the past decade. The following figures of the production of galena from Belgian mines, and of the output of Belgian smelting works, are taken from M. Ern. Harzé's official statistics for the year 1883:

Production of galena and lead in Belgium.

Years.	Galena.	Lead.	Years.	Galena.	Lead.
	Metric tons.	*Metric tons.*		*Metric tons.*	*Metric tons.*
1870	13,380	10,034	1877	11,542	7,733
1871	11,549	9,287	1878	13,477	8,141
1872	11,887	6,535	1879	9,384	7,961
1873	11,280	6,387	1880	5,434	8,204
1874	10,894	8,020	1881	3,741	7,651
1875	10,567	7,459	1882	2,918	8,805
1876	12,422	7,275	1883	508	8,391

These figures clearly show how Belgian works are becoming more and more dependent upon foreign ores. For 1882 this is exhibited by the following details:

Statistics of Belgian lead works.

Items.	1882.	1883.
Number of works	5	3
Number of workmen	378	401
Average daily wages ... francs	2.75	2.75
Ores consumed:		
Belgian ... metric tons	3,517	508
Foreign ... do	8,765	9,643
By-products ... do	12,190	8,588
Lead produced ... do	8,805	8,391
Silver produced ... kilograms	10,154	10,487

In 1882 the production, imports, exports, and apparent home consumption in Belgium were as follows:

Lead imports, exports, and consumption of Belgium.

Items.	Metric tons.
Production of lead	8,805
Imports of lead	4,983
Exports of lead	7,707
Apparent home consumption of lead	6,081

France.—The latest official statistics for France available are those of 1882, showing a production of 8,076 metric tons from ores, nearly three-quarters of which were imported from Greece, Spain, and Sardinia. The only lead mine of any importance in France is that of the Pontgibaud Company, an English corporation. France, however, does quite a large desilverizing business, having treated nearly 21,000 tons of base bullion, chiefly Spanish. The imports of lead into France were, in 1882, 65,369 tons, and the exports 5,301 tons, thus showing an apparent home consumption of 68,144 tons of lead.

Austria-Hungary.—According to official statistics kindly forwarded by C. von Ernst the production of lead in Austria and Hungary was as follows, taking litharge at 80 per cent.:

Production of lead in Austria and Hungary.

Years.	Austria.	Hungary.
	Metric tons.	*Metric tons.*
1879	8,542	2,112
1880	8,517	1,900
1881	8,783	1,850
1882	11,113	1,843
1883	11,134	1,800

The imports of Austria in 1883 were 1,237 tons of lead and manufactures of lead, and its exports 482 tons, thus showing that the home industry fully covers the wants of the country, which are per capita very low.

Other countries.—Among the other countries which produce lead Greece must be specially mentioned. The Laurium Company, an association of French capitalists, has for years worked cinder heaps left by the ancients, and has reopened the mines wrought by them, with considerable success. For 1883 the Greek Government estimated the profits of the concern for purposes of assessment at 1,088,244 francs.

Italy and Sardinia turn out some lead, and in America Mexico exports a moderate quantity, chiefly to Great Britain. Asia, Africa, and Australasia contribute practically no lead to the commerce of the world.

LEAD SLAGS.

BY MALVERN W. ILES.

Smelting is a chemical operation, and a study of the nature of slags forms the science of smelting. It will therefore be seen that the field is an exceedingly broad one, and that even in the treatment of a particular kind or class of slags, as produced by shaft furnaces for the treatment of argentiferous lead ores, it will not be possible within the limits of this paper to give all of the important data, but simply to briefly state such salient points as have come within the notice and experience of the writer. The subjects discussed will be classified as follows:

I. *Physical properties.*—(1) Density; (2) crystalline form; (3) color; (4) luster; (5) fluidity; (6) fusibility; (7) magnetism; (8) friabilty; (9) influence of slow and rapid cooling.

II. *Chemical properties.*—(1) General composition; (2) modes of decomposition; (3) quantitative analysis; (4) analytical data; (5) types.

PHYSICAL PROPERTIES.

Density.—The specific gravity of slags formed in argentiferous lead smelting has been found to be very variable. The minimum noted was 3.3 and the maximum 4.16; the best slags, however, may be stated to have a density of 3.4 to 3.65. Iron, barium, and lead cause high specific gravities, while silica, lime, and alumina have a tendency to diminish the weight. The average density of one hundred samples taken daily in 1880, at Leadville, during very fair work was found to be 3.691. A series of experiments was conducted on this subject for over a year without arriving at any very positive or satisfactory results. It is now believed that difference in density alone cannot be used as an infallible guide, but should only be regarded as an auxiliary for a thorough study of slags.

Crystalline form.—Most slags show some tendency towards crystallization. A few have been noted in which the crystallization was very imperfect, yet the silver and lead losses were small; these, however, were exceptions and not the rule. In general, the more crystalline a slag is the better it is, considered both from an economical and a metallurgical standpoint.

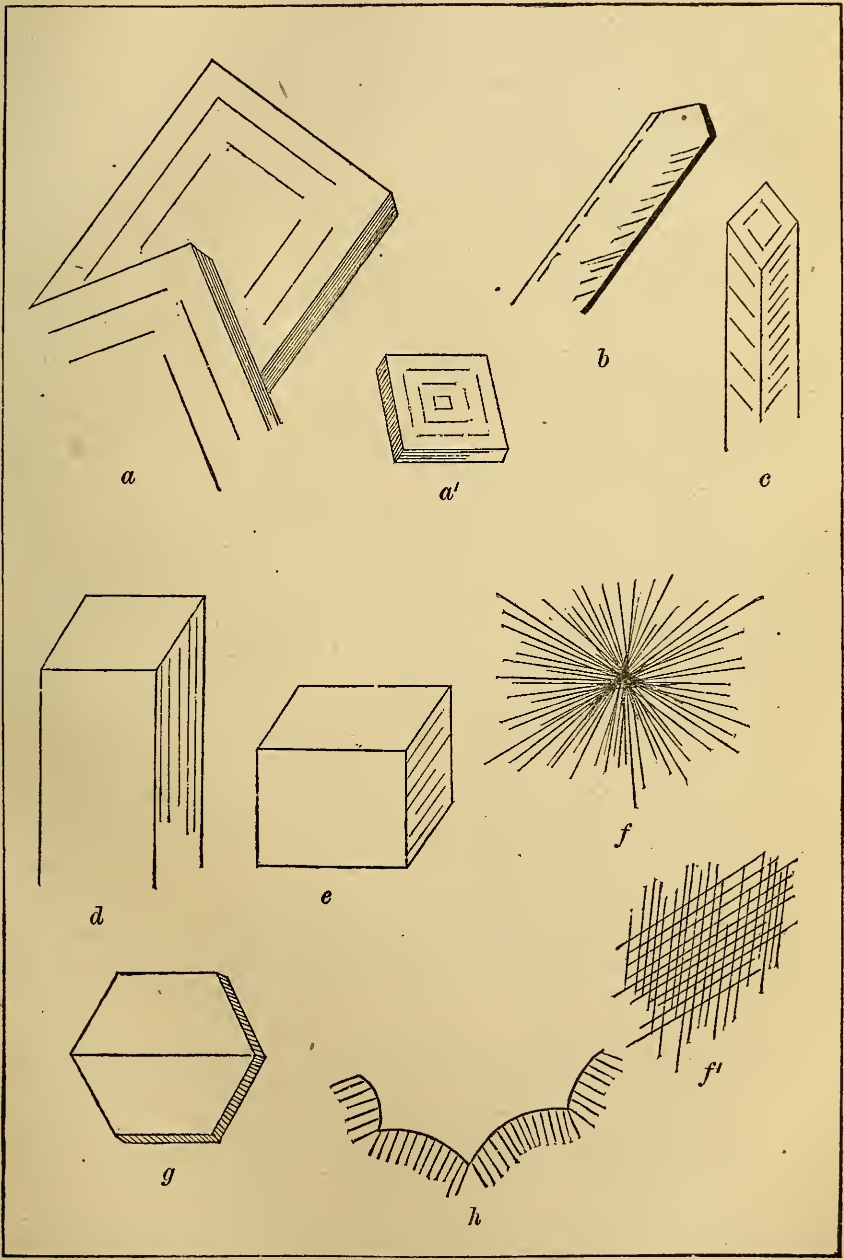

Fig. 5.—Crystalline forms of lead slags.

The center or "heart" of a cooled pot or cone of slag is always found to be the most crystalline; this tendency diminishes outwardly in all directions until next to the surface is a thin crust or scale devoid of a crystalline structure and presenting a thin vitreous or glassy scale. This scale is the result of rapid cooling of the slag as it comes in contact with the iron pot. If the grade of bullion produced is not quite high (say over 300 ounces of silver per ton) and the lead charge is not very low, it is rare to find a very crystalline slag containing more than 1 per cent. of lead or more than 2 ounces of silver per ton; generally these markedly crystalline slags show a much smaller loss than this. A very careful study of the crystalline form of lead slags will unquestionably enable a skilled metallurgist to identify the type of slag produced, to tell within reasonably close limits the general composition, and to form a comprehensive idea as to the losses in both lead and silver.

The most important crystalline forms of slags are either large thick plates or leaves; thin plates, often semitranslucent and frequently marked with striæ; monoclinic prisms, which may be either inclined or rectangular; several modifications of the cube; delicate needles, which may or may not radiate from a central nucleus; hexagonal plates; and lastly, what may be termed for convenience botryoidal and pectolitic crystallization. These various forms are shown in the diagrams on page 441. There seems to be a distinct connection or relation between the crystalline form and the chemical composition of these slags, as it will be endeavored to show when the subject of "types" is considered.

Color.—Lead slags are almost always black, or of some dark shade. The darkest slags are those containing the most iron; yet iron will sometimes give either a reddish tint due to the presence of a small amount of Fe_2O_3, or have a slight greenish cast. Lime tends to lighten the color, giving the slag a stony or earthy appearance. Manganese in large quantities gives a reddish to amethystine hue, and when the manganese is associated with 20 per cent. CaO, and over, the slag very often has a resinous color, closely resembling blende. Zinc in the presence of alumina, some manganese, and much silica (from 36 to 37 per cent.) gives a color very closely resembling porcelain or obsidian; this is especially true of the outer rim of the pot (see analysis No. 82, page 456). Lustrous black slags are always due to the presence of much iron. Some exceedingly siliceous slags (38 to 42 per cent. silica) have a greenish cast.

Luster.—Most of the slags formed in lead smelting are vitreous, although the high lime and also the very high iron slags are not as a rule vitreous. The luster is rarely pearly, often resinous; submetallic, splendent, also pitchy—in short, they possess lusters analogous to those of the unisilicates and bisilicates as formed in nature.

Fluidity.—Thick, viscid slags almost invariably occasion losses in both silver and lead; generally the more fluid a slag is the more perfect will be the separation of lead, and consequently that of the silver. When the fluidity is entirely dependent upon iron there is a liability to iron crusts, and these will then produce great losses. Scientific smelting should aim at obtaining a fluid slag, a slag built up to approach some one of the recognized types. Silica is the chief cause of viscidity in slags, although even a properly calculated slag will sometimes run viscid owing to a lack of fuel, or soon after starting up or "blowing in" a furnace. During heavy snows or rains, or in exceedingly cold weather, the slag may run viscid because of an insufficiency of fuel.

Manganese increases the fluidity of slags to a marked degree, often rendering even siliceous slags fluid. Lime may or may not make a fluid slag; most high lime slags flow with a smooth oily flow, fluid when hot and either stringy or brittle according to the other ingredients present. Some slags are so fluid and smelt so fast, especially when the ore charge is coarse, that they do not allow a perfect separation of lead and silver; under these circumstances the furnace is said to "drive too fast."

Fusibility.—Generally the more fusible slags are the more economical they are; they require less fuel, drive faster, often prevent "over fire," cause a more perfect separation of the valuable metals, and should be the aim of the lead smelter. Easily fusible slags do not always give rise to very bright tuyeres, although they usually show a light, and the scale or crust immediately in front of the tuyere is quite thin.

Silica lessens the fusibility; manganese and iron always increase it; while magnesia and zinc rarely, if ever, cause a more fusible slag. Alumina may or may not increase the fusibility of lead slags. If the percentage of silica is low alumina plays the rôle of an acid and hence increases the fusibility; if, however, the percentage of silica be high, then alumina acts as a base and hence lowers the fusing point of slags. This statement has been arrived at after many long and extensive experiments, involving the smelting of many thousand tons of ore. The closer certain recognized slag types are approached, the greater will be not only the fluidity but also the fusibility. It is, however, not always an economical mode of procedure to adhere too rigidly to any general form of slag.

The subject of the fusibility of slags cannot but be regarded as one of the chief points to which the lead smelter should direct attention in the treatment of silver-bearing lead ores by means of the shaft furnace. Professor Gordon, in his translation of Gruner's "Studies of Blast Furnace Phenomena," makes the following valuable remarks: "There is, however, a considerable difference in the temperature required for the complete formation of different slags. According to Plattner's experiments, although the temperature of fusion of the slag itself, when formed, varies much less for different proportions of acid and bases, forming singulo-silicates, bisilicates, and trisilicates, the temperature at which slags are formed varies considerably. In general, singulo-silicates require a higher temperature for formation than bisilicates; and of singulo-silicates those of alumina form at 2,400° C., magnesia form at 2,200 to 2,250° C., baryta form at 2,100 to 2,200° C., lime form at 2,100 to 2,150° C., iron and manganese form at 1,789 to 1,832° C.

"The silicates of oxides of manganese and iron (protoxide) differ very little from each other. The bi- and trisilicates of the different earths are formed at a lower temperature. Of the bisilicates those of baryta and lime form at 2,100° C., baryta and alumina form at 2,050° C., lime and magnesia form at 2,000° C., lime and alumina form at 1,918 to 1,950° C.

"The temperature required for the formation of compound silicates from the earths composing them is very much higher than that at which slags which have been already fused can be melted. As the slags coming from smelting processes are seldom formed by fusing together these independent components, but more frequently from a mixture of silicates already formed, partly from the ores, etc., and generally of manifold combinations of the oxides of the earths, the temperature required for the formation of the new slag or compound silicates will lie between their point of fusion and the temperature which would be necessary to form this new slag from the simple substances.

"Refractory slags, which are always indications of faulty working of the furnace, arise either from insufficient temperature or from injudicious combination of the charges—as when too much silica and too little of the bases, or the contrary, are present, or if among the bases there be an excess of alumina and magnesia. Such slags are recognized by their pasty nature, their earthy, half-fused appearance, and by the airholes pervading them. On the other hand, the charge is a good combination when the slag flows out at a good consistency, as free from metal as possible, and when, for a given consumption of fuel, the maximum of ores can be used."

Dr. Percy, while objecting to the principle of Plattner's method, because it assumes that alloys of gold, silver, and platinum fuse at the mean temperature of the component parts, says we may accept his results as affording practical information of value. "The melting points of metals and their alloys are fixed and unvarying, except under extraordinary conditions of pressure, and as they extend through a very wide range of temperature they may be conveniently employed in the determination and comparison of high temperatures." Plattner himself considered that he had only determined temperatures "correctly proportioned to each other, and not absolute thermometric limits."

In this connection it will be well to quote a few lines from Overman, which, while they are in the main correct, contain one or two statements which are subject to limitations and corrections when viewed from a lead smelter's standpoint. "If," says Overman, "a compound of lime and silex melts at 3,000° C., that of protoxide of iron and silex at 2,000°, and that of a silicate of oxide of lead at 1,000°, the mean heat of the three, by which they melt when mixed together, is not

$$\frac{3000^\circ + 2000^\circ + 1000^\circ}{3} = 2000^\circ$$

as their various degrees indicate, but it may be only 1,500°, and in this case even lower than that." The above statement is unquestionably correct; then follows this remark: "The greater the number of elements in a slag the more fusible it becomes; it is, therefore, of the utmost importance in all smelting operations to multiply the kinds of ores; this produces fusible slags and fusible metals." In general, multiple bases do produce a more fusible slag than where only a few bases are present; but there are certain notable exceptions to this rule or law in the cases of zinc, alumina, and magnesia. No intelligent lead smelter would for a moment think of adding zinc simply that there might be a larger number of bases to enter the slag; nor would it be policy to add either alumina or magnesia. For some reason, not as yet very clearly understood, magnesia has been found to increase the silver losses to a remarkable extent. The latter portion of the above-quoted passage in regard to multiplying the different kinds or ores is the proper mode of procedure from other considerations aside from the simple fact of fusibility. Overman also says: "Slags should be as fusible as the metal which is to be smelted with their assistance. If they are more refractory than the metal, the slag causes it to assume a heat by which more or less of it is evaporated." Since lead melts at or about 325° C., the probabilities are that very few lead slags have this low-fusing point.

While there are a number of substances which will make fluid slags, yet, owing to the cost and the difficulty of procuring them in large quantities, we must therefore of necessity use either iron, lime, or manganese. The proper and economical use of these bases in localities where the ores to be smelted are highly siliceous (and this is generally the case) becomes a matter of either profit or loss in carrying on this industry. The problem, in other words, may be stated thus: How shall we cause the largest amount of silica to be fluxed off into the slag and at the same time use as little costly bases as possible, producing a fusible and clean slag?

Magnetism.—In December, 1879, it was discovered that the slags produced at the old works of the Grant Smelting Company were all magnetic; thinking that perhaps this might be peculiar to this kind of slag, one hundred and eight samples were collected, including specimens from all the furnaces of the different works at that place, and in every case the same property was observed. The entire mass of some slags was found to be attractable by the use of an ordinary horseshoe magnet. An attempt was made to discover some relation between the intensity of the magnetism and the lead and silver losses; but so far without obtaining altogether satisfactory results.

Experiments were instituted clearly demonstrating that this magnetic property was not due to fine particles of metallic iron mixed with slag. It was also noted that it was exceedingly rare to find an ore from this locality which is not in part attracted by the magnet, and by panning or concentrating these ores the black magnetic oxide of iron (Fe_3O_4), so common in placer mines, will be found. It may therefore be said, as a partial explanation, that this magnetic sand passes into the slag giving it this property. It is possible that the reducing power of these furnaces was imperfect, for example, due to a lack of fuel; but the smelters at this time were inclined to use more fuel than has since been found necessary for good work. An oxidation at the tuyeres may also give rise to this phenomenon, as, for example, by using too strong a blast. I have found that even siliceous slags are more or less magnetic; all lead slags containing from 25 to 55 per cent. of ferrous oxide and even high lime slags also are magnetic; hence the chemical composition seems to have little or no effect upon the magnetic property of slags. Of course, if magnetic oxide of iron enters the slag *as such*, it implies necessarily a waste of precious flux; yet I am of the opinion that the magnetic property is due to (1) an unavoidable admixture of some ferric silicate; (2) to the ferrous silicate itself; and (3) in many cases to the presence of iron matte; this is especially true where very impure ores are treated and the production of matte is large. The mineral fayalite is a silicate of protoxide of iron, yet it is attractable by the magnet. I find that iron matte (Fe_2S) is always more or less magnetic, therefore a part of the magnetic property is often due to this cause. The slags produced at all the prominent smelting works in this country show more or less a magnetic property, and samples of slag from many of the abandoned dumps have this same characteristic; therefore I am led to the conclusion that this is a general property of lead slags.

If it can be shown that the magnetism of lead slags is due to sesquioxide of iron, more than nine-tenths of all the analyses of lead slags are incorrect, as it is exceedingly rare to find a slag analysis in which sesquioxide of iron is reported.

Friability.—The friability or brittleness of slags is dependent upon the number, kind, and amount of the bases present. Generally the more siliceous a slag is the tougher it is, and the greater the amount of base the more brittle it is, though the latter statement is subject to certain limitations. Slags not containing over 33 to 34 per cent. of silica are usually brittle; whenever the silica runs up to, say, 35 to 40 per cent. we have quite tough slags unless the slag has very little iron and a large amount of lime (say from 22 to 30 per cent.) A slag containing 30 per cent. SiO_2, 50 per cent. FeO, and 3 to 8 per cent. CaO, is not very brittle, yet the amount of base is large in comparison with the amount of acid present. Slags of the type $30\% \ SiO_2+40\% FeO+20\% CaO$ are always brittle; so also are the slags containing $34\% SiO_2+34\% FeO+24\% CaO$.

As an example of tough slags analyses Nos. 18, 32, 36, 40, and 97 (pages 454 to 456) may be cited. The following analyses are examples of brittle slags: Nos. 7, 13, 14, 45, 46, 55, 56, 57, 64, 65, 66, and 67. The most brittle slags I have ever seen are those numbered 64, 65, 66, and 67 in the table of analyses. Whenever the amount of matte produced is quite large it is often best to form a slag which is slightly tough, otherwise there will be difficulty in obtaining a close saving of the matte

If the ores contain much zinc this causes the matte cake to adhere closely to the bottom of the slag cone; in this case it is best not to have the slags too brittle. Generally the brittle slags are freer from both silver and lead. The brittleness is the result of a highly crystalline structure.

Influence of slow and rapid cooling.—The more slowly a newly-drawn pot of slag is cooled, the more perfect will be the crystallization. Such slowly-cooled slags have a certain fixed fusing point, and are generally only imperfectly soluble in any of the strong mineral acids. This slag upon breaking open a pot ordinarily shows a well defined crystallization when the type is closely approached, and on the outer edge there will be a thin crust or scale of glassy material. If slags are cooled rapidly the crystallization will be imperfect, and if very rapidly the structure is entirely changed and often crystallization is entirely absent. If melted slag is either poured or plunged into water, the crystallization is entirely prevented, and the mass (if not in too large quantities) will show a glassy appearance not unlike that of obsidian. Slags thus rapidly cooled have suffered a very remarkable and hitherto unrecorded change; they will be found to have a much lower fusing point, and by powdering them they will be found to be entirely soluble in any of the strong acids, especially in hydrochloric acid. By taking advantage of the last named fact, it will be readily seen that fusions for the analysis of slags are entirely unnecessary in connection with this industry.

It is generally customary at lead smelting works to turn a stream of water on the slag trough or "slag runway" soon after tapping a pot of slag, thus chilling and rendering brittle that portion which has adhered to the trough, and this is most always thrown away, injudiciously so it is thought, since this portion will not only contain many matte globules, but also very often pellicles of lead which may have lodged upon the trough either from a "blow-pot," or from a leaky breast. This rapidly cooled slag is not only generally richer, therefore, than the main body of the slag, but, if for no other reason, it should be saved for these uses: It melts at a very low temperature and hence is valuable for "blowing-in" a furnace; to be fed after "barring the hangings;" and it also serves a most admirable purpose in keeping down or preventing the so-called "over fire" or "fire tops."

CHEMICAL PROPERTIES.

General composition.—Lead slags are chiefly silicates of iron and lime; aside from these bases, manganese not infrequently plays an important part, as seen by analyses Nos. 9, 36, 37, 49, and 50. Zinc, alumina, baryta, and magnesia also sometimes enter slags as important constitutents, but these bases when present to any considerable extent will occasion trouble and are to be avoided if possible.

In argentiferous lead smelting the slag will always contain some lead and silver; in many cases these elements only exist in minute traces.

From the fuel the slags derive some potassium and sodium and also phosphorus, but the amount is however quite small. Sulphur will always be found; the amount usually varies from 0.5 to 2 per cent. When copper ores enter the smelting mixture, some of this metal will also enter the slag, particularly in re-working the cupiferous matte; Dr. Wedding reported 0.27 per cent. Cu_2O in the Saint Andreasberg slag in one instance, and in another case 0.50 per cent. In an analysis of the Clausthal slag, made in 1870, Hampe reported $NiO + CoO$, Cu_2S, and SbS_3; the phosphorus was reported as PO_5. Certain lead slags of Spain were once used as a source of vanadium. At Leadville, at one time, no less than three different mines were yielding vanadium in noticeable quantities. I have known a large ore mixture or "bed" to be smelted which contained no inconsiderable amount of these vanadium ores, and have detected vanadium in ores from the following different Leadville mines: Morning Star, Evening Star, Waterloo, Etna, and especially in ore from the Park mine. The Little Ellen mine, at Red Cliff, Colorado, was also found to contain a green vanadium mineral (supposed to be descloizite). Owing to the above-mentioned facts, I think that vanadium is no uncommon constituent of the Leadville slags.

Aside from the above-mentioned elements, which are chemically combined, I have noted certain abnormal slags containing as a mechanical mixture portions of quartz varying in size from a mere speck to large white, usually rounded, pebbles from 2 to 3 inches in diameter. These pebbles were worked out through the tapping hole with difficulty, and when broken showed a dull, white color resembling that of unglazed porcelain. Then again I have noticed sesquioxide of iron, sometimes in pieces an inch large; also pieces of quicklime; this, however, has only been observed when the furnace was being "blown out." In one instance quite a large piece (a quarter of an inch in length) of sulphide of zinc was found which was highly crystallized; this occurred at the very bottom of a cone of slag after breaking off the matte cake.

Before passing from this subject, it may be well to mention that by closely observing the very top of a pot of slag there will very often be found in blistered cavities exceedingly delicate needles; sometimes these crystals will appear almost white, then again of a yellowish tint (this is supposed to be due to oxide of zinc), and again others of a distinctly bluish tint. These bluish crystals have been found to contain both sulphur and lead, and are perhaps a subsulphide. These delicate crystals I have most frequently seen when the production of matte was large, although one of my metallurgical friends informs me that he also has noticed these crystals when scarcely any matte was formed. Shot-like globules of metallic lead have been observed in certain highly siliceous slags. Whenever the production of iron matte is unusually large it is not an uncommon thing to find rounded globules of it in the slag; this is particularly the case on the very outer rim of the pot.

Modes of decomposition.—The ordinary method of fusing slags with carbonate and nitrate of soda in a platinum crucible will sometimes give good results; but since the slag always contains more or less lead it will be readily seen that the analyst runs the risk of either injuring or completely spoiling the platinum crucible by the reduction of metallic lead. A very good method of proceeding when the samples are not taken according to the method to be subsequently described, is to powder the slag well in an agate mortar, then digest with strong hydrochloric acid, evaporate once to complete dryness upon the water bath; then add more hydrochloric acid, filter, and fuse (or, better, agglomerate, or semi-fuse) the residue with sodium carbonate in a platinum crucible, and proceed as usual according to the well known method for the determination of insoluble silicates.

The above mode of procedure is found somewhat long for the practical uses in connection with industrial works, where time is a great desideratum. To facilitate the fusion and also to prevent the liability of destroying costly platinum crucibles, I have for a long time used a method of fusing the slag in a silver crucible with caustic potash and then proceeding as usual in the analysis. The method last described has the advantage that the heat required for the fusion is quite small, in fact an ordinary alcohol lamp is found sufficient; and as many laboratories connected with the lead smelting works have neither gas nor the improved gasoline burners, the method is therefore very serviceable. The disadvantage is that the silver crucible is always slightly attacked by the caustic alkali, and when a complete analysis is to be performed the silver gives trouble in some of the determinations. This difficulty is, however, entirely overcome if a platinum crucible is heavily plated with gold, as has been suggested by W. Bettel in the *Chemical News*.

A method which I will now describe has been used for several years in connection with these works and leaves little to be desired. If in taking the laboratory sample we use an ordinary steel bar, throw aside the crust from a newly-drawn pot of slag, dip the reversed end of the bar about 2 inches into the molten slag, then quickly plunge into a bucket of water, and use this sample for analytical determinations, it will be found that all slags made in lead smelting will be entirely decomposed by strong hydrochloric acid, giving rise to perfectly pure gelatinous silica. By using a small amount of acid, and with a little practice, one can determine the silica, iron, and lime contained in a slag in less than two hours.

Quantitative analysis.—After taking the slag sample, as previously indicated, weigh out from half a gram to one gram, transfer to a covered casserole, add from the wash bottle a few drops of water, stir well, and add concentrated hydrochloric acid; again stir, and digest over a free flame for a few minutes. The addition of water and the stirring prevent the slag from clotting or caking upon the bottom of the vessel. Now add a few drops of nitric acid, both to insure the oxidation of the iron and also to decompose the few particles of lead sulphide which are apt to form during the first addition of hydrochloric acid, and rise upon the sides of the vessel. Sometimes these black specks are due to carbon, which will, of course, be burned off in the ignition of the silica. Evaporate to dryness upon the water bath; this is not a long operation if the analyst uses a minimum quantity of acid (say, 6 to 8 c. c.). After the evaporation is completed add a few drops of water, just sufficient to moisten the mass, and evaporate a second time. Now add a slight excess of concentrated hydrochloric acid; warm, dilute, and filter, washing the silica with boiling water, and drop a small amount of hydrochloric acid around the edges of the paper; wash again with water. The moist residue, with the paper, is transferred directly to either a porcelain or a platinum crucible, placed in an ordinary scorification cup, and dried before the assay muffle until the paper begins to carbonize. It is then placed in the muffle for about five minutes, removed and allowed to cool, and the silica is then weighed. The silica will be found perfectly white, not even tinted with iron, and the determination is as accurate as if a fusion had been performed.

For the determination of the iron it is advisable to take a second portion of half a gram, boil with hydrochloric acid to complete decomposition in a casserole, then dilute with water and add a small piece of unamalgamated zinc directly into the covered vessel. After a few minutes the cover is removed, washed, and the contents of the casserole are cautiously transferred by decantation to a large beaker, and diluted with water up to 500 c. c.; now add rather a large amount of concentrated sulphuric acid (say 25 c. c.) and titrate the iron with a standard solution of potassium permanganate.

It will be noted that it is entirely unnecessary to remove the silica in order to determine the iron, and furthermore time is saved by reducing the iron by unamalgamated zinc directly in the vessel in which the decomposition of the slag is effected. For commercial work a solution of permanganate is made by dissolving 5.686 grams of the salt in one liter of water.

For the estimation of lime two methods are used, according to the degree of accuracy to be attained. If, for quick work, we wish to ascertain the percentage of lime we use the filtrate from the silica as follows: Heat this filtrate, add ammonia to a slight alkaline reaction, then add a saturated solution of oxalic acid to dissolve the iron; boil for a few minutes, allow to stand twenty-five minutes, filter hot, wash well, and transfer to a casserole; add some hot water and sufficient hydrochloric acid to dissolve the calcium oxalate, filter, and dilute with cold water. Now add rather a large amount of sulphuric acid, heat to boiling, and titrate with the same solution of permanganate as was used in the iron determination. If a greater degree of accuracy is desired the iron and alumina are removed as basic acetates, then the manganese is separated by bromine water, the zinc removed by sulphureted hydrogen, and the filtrate treated according to the usual methods for estimating the lime.

Some manganese will invariably pass into the filtrate when the iron is precipitated by ammonia and will come down with the lime, thus introducing an error to the extent of its presence. When, however, the amount of manganese is small in comparison to the amount of iron we can often use the first-mentioned method with a great saving of time.

For the determination of the manganese, from one to two grams of the finely divided slag is used, according to the amount present; this is treated in a casserole with concentrated hydrochloric acid, with the addition of a small amount of nitric acid in order to convert all the iron into the ferric form. Now boil, and add sulphuric acid, gradually replacing all of the nitric acid, and also hydrochloric acid; the success of the operation depends upon the entire removal of the hydrochloric acid. Dilute to about 150 c. c. and boil; add an emulsion of zinc oxide in large excess, by which the iron is precipitated as ferric hydrate; filter off the silica and oxides of zinc and iron, and dilute to 500 c. c. Some writers recommend, before the addition of zinc oxide, neutralizing with sodium carbonate, and then clearing the solution with a few drops of nitric acid; this in practice is found to be unnecessary. Draw off from the diluted liquid, after thorough mixing, an aliquot part (say 100 c. c.), transfer to a casserole, heat to boiling, and titrate with frequent stirring with the same permanganate as was used for the iron and lime until the first rose tint is observed. Calculate the percentage of iron corresponding to the permanganate used, and multiply this percentage by 0.2946 (= per cent. Mn). The manganese scheme as above stated is highly recommended, both for its rapidity and accuracy; in fact there is no known method which I think will compare with it for technical and scientific work.

The sulphur is determined by the "Fahlberg-Iles" method as follows: Fuse one to two grams of finely divided slag in a silver crucible (or gold-lined platinum crucible) with twenty-five grams potassic hydrate for twenty minutes; cool, dissolve in water, filter off the hydrated oxides of iron, etc.; now add 30 c. c. bromine water, and then concentrated hydrochloric acid to an acid reaction; boil off excess of bromine, filter if necessary, add barium chloride, and proceed as usual for the treatment of barium sulphate.

If other constituents are to be determined the methods are followed as given by Fresenius, Rose, Sutton, Cairns, or Hart.

Analytical data.—In the table of slag analyses, the date indicates when the analysis was performed; in most cases the time of production and the date of analysis do not widely differ. The numbers simply serve to distinguish one kind of slag from another.

The fire assays were in every case carefully determined. The specific gravity determinations were in almost every case found by use of the

Jolly spring balance. Some of the earlier determinations of silica are a trifle too high, but by far the largest number of tests were the result of careful fusion. Lately it has been found that accurate silica determinations could be obtained by taking the slag samples in a manner previously mentioned. The iron was determined by the use of a standard solution of potassium permanganate, with, except perhaps, those given by Mr. R. C. Ballard. The lime tests were made partly by gravimetric and partly by volumetric tests. Some of the manganese tests are by the well-known bromine method and weighed either as a phosphate or an oxide of manganese; all of the more recent determinations were made by using the excellent zinc oxide method, the details of which have been fully given under the heading of chemical analysis. The alumina, magnesia, and lead determinations were made by use of the good old fashioned methods. The sulphur test was performed by fusion with caustic potash as above indicated.

In the table of analyses there may be found every kind or type of slag produced in connection with the lead-silver smelting industry I have been able to find up to the time of writing (July, 1884). In several cases certain types have been repeated to show how the lead and silver losses vary under different circumstances, as for example when producing high or low grade bullion. The extreme limits of lead-slags may be stated as follows:

	Per cent.
SiO_2	26 to 41
Fe + Mn	18 to 35
CaO	5 to 35

It is exceedingly rare that the extremes will work satisfactorily for long campaigns; yet often to accomplish certain results, as for example freeing the crucible of the furnace from obstructions or crusts, one can very materially prolong the life or campaign of the furnace by the use of certain extreme slags. By very careful observation based upon analytical data the metallurgist can determine whether the trouble arising from the crucible be due to a siliceous accumulation, an iron crust, or a charcoal, coke, zinc, or lead crust; by acting upon any of these crusts at the right time and for a sufficiently long time with certain slags we can generally eliminate these troubles.

Most of the best slags will have a composition ranging somewhere within these limits:

	Per cent.
SiO_2	31 to 36
Fe + Mn	23 to 30
CaO	14 to 25

And to still further restrict the limits, we may say that the best work is done, the campaigns are longest, and in the short the most economical slag produced, when its composition lies within these very narrow limits:

	Per cent.
SiO_2	31 to 34
Fe + Mn	24 to 27
CaO	14 to 25

In some very exceptional cases, and on certain ores, it may be best to have a slag containing less than 31 per cent. or more than 34 per cent. silica; and the same may be said in regard to the iron, manganese, and lime bases. The prices paid for iron and iron fluxes, taken in connection with the impurities to be contended with, should in short determine the type of slag to be produced. To decide exactly what is the best slag for the treatment of ores where zinc, alumina, magnesia, baryta, and arsenic enter either singly, or all together, in large quantities, is necessarily a very intricate and difficult problem. For the reasons just cited no one slag can be said to be the best under all circumstances. A careful investigation of the analytical data as given in the table, will, I think, present some very interesting features, and at the same time disclose some hitherto unrecorded facts.

Analyses of argentiferous lead slags.

Date.	Number.	Fire assay.		Specific gravity.	SiO_2.	FeO.	Fe_2O_3.	=Fe.	CaO.	MnO.	Al_2O_3.	MgO.	PbO.	ZnO.	PbS.	S.	Total.	Analyst and remarks.
		Ounces Ag.	Per cent. Pb.															
April 27, 1880	1	2.00	3.00		28.10	43.92	4.33		5.60	5.58	1.85	3.54	5.23			.98	99.13	M. W. Iles.
April 20, 1880	2	2.00	5.75	3.85	26.45	37.11	7.88		8.38	5.20	4.29	3.23	6.19			.55	99.28	Do.
April 24, 1880	3	3.00	4.50	3.80	28.50	42.21	9.48		4.50	5.21	.62	3.06	6.51			.82	100.91	Do.
May 5, 1880	4	2.00	1.50		29.15	38.79	6.37		6.97	6.97	1.31	4.25	5.88			.97	100.66	Do.
June 7, 1880	5	2.50	3.00		37.60	41.54				5.02	4.45							Do.
July, 1880	6	2.50	3.15	3.62	31.50	30.40	12.23		6.00	4.65	4.40	2.99	5.46			1.30	98.93	Do.
January 15, 1880	7	1.00	1.25	3.57	30.20	36.19			22.80	3.81	4.29	.14	2.36			.62	100.41	Do.
	8				29.27	45.17			8.03	3.91	4.56	4.60			3.91		99.45	R. C. Ballard.
	9				31.32	39.16			8.52	7.96	5.79	7.79			2.50		103.04	Do.
	10				34.12	37.65			7.54	4.11	6.23		4.45					Do.
October 7, 1880	11	Trace.	1.00		33.50	49.88												M. W. Iles.
January 17, 1881	12	1.00	1.50	3.56	39.10	39.09		(30.40)	8.30	5.02	*a*.85	3.80	2.65			1.19	100.00	Do.
July 12, 1881	13	.50	.90	3.45	33.40	34.71		(26.99)	25.10	2.00	2.44	Trace.	1.57			.71	99.93	Samuel James.
	14				31.70	35.62		(27.70)	26.50	2.58	2.10	do	Trace.			.88	99.38	Do.
	15				31.20	40.35		(31.38)	19.90	2.35	2.78		3.79			.55	100.92	Do.
July 16, 1881	16	1.75	3.50		36.40	38.31		(29.80)	10.00									M. W. Iles.
July 27, 1881	17	1.75	2.25		35.80	41.65		(32.40)	12.40	3.35	2.13	Trace.	3.24			.86	99.43	Do.
July 30, 1881	18	1.25	2.00		40.20	33.43		(26.00)	16.60	3.54	2.86	do	3.12			.50	100.25	Do.
July 29, 1881	19	1.46	2.16		36.00	41.14		(32.00)	13.20	3.54	*a*2.04		3.23			.85	100.00	Do.
February 28, 1882	20				37.96	37.14		(30.00)	12.84	4.24	4.33	Trace.	3,25			.90	100.66	Do.
May 7, 1882	21	Trace.	1.75	3.50	35.40	38.18		29.70	13.50	2.75								W. T. Page.
March 29, 1882	22	1.75	2.50		34.10	45.00		35.00								1.52		W. R. Boggs.
1879	23	1.79	1.60	3.48	34.79	37.69		29.32	13.68	3.87								W. R. Boggs. Average of 15 samples.
	24	1.75	1.25		33.00	49.60		38.60	10.80									W. R. Boggs.
	25	5.00	6.50		29.00	43.00												Do.
	26	7.00	8.50		34.60	44.20		34.40	5.80									Do.
1880	27	12.00	1.75	3.75	25.80	43.80			10.10									Do.
August 30, 1882	28	1.50	3.00	3.65	33.80	47.30			12.80	1.60						1.84		Do.
September 1, 1882	29	Trace.	1.00		31.80	33.70			25.20	1.10		Trace.	1.60			1.62		Do.
March 21, 1883	30	.90	1.80	3.60	33.50	37.90			17.05									W. T. Page.
	31	3.80	2.10	3.47	33.25	31.90			19.40									Do.
1883	32	.75	1.25		35.95	24.40			25.05	4.75		Trace.		.30		2.67		Do.
March 21, 1883	33	5.10	3.10	3.78	32.00	42.70			14.20									Do.
May 23, 1883	34	.25	1.30	3.75	30.00	43.20			13.30	4.55								Do.

a By difference.

June 14, 1883	35	3.10	10.00	......	28.00	30.94	......	......	16.20	......	......	......	......	......	......	......	......	W. T. Page. Charge incorrectly calculated. Mn. very large; not determined.
June 20, 1883	36	.90	2.00	......	35.40	20.36	......	......	14.80	14.83	......	......	......	......	......	......	......	W. T. Page.
	37	1.25	1.25	......	34.00	23.04	......	......	14.80	12.70	......	......	......	......	......	......	......	Do.
Jan., Feb., 1884	38	.95	1.41	......	36.76	34.45	......	......	16.61	5.38	......	......	......	......	......	......	......	W. T. Page. Average of 8 analyses; two months' run.
1879	39	3.00	3.00	......	31.00	41.52	......	......	15.00	1.93	......	......	......	......	......	......	......	W. T. Page. Abandoned dump.
	40	3.00	3.70	......	38.40	40.62	......	......	7.00	7.48	......	......	......	......	......	......	......	Do.
February 24, 1884	41	1.00	1.50	......	32.50	36.90	......	......	19.00	3.87	......	......	......	......	......	......	......	W. T. Page.
December 27, 1882	42	1.00	1.75	......	37.40	35.22	......	......	14.90	......	......	......	......	......	......	......	......	Do.
February 1, 1883	43	Trace.	1.50	......	38.40	33.90	......	......	13.20	......	......	......	......	......	......	......	......	Do.
March 14, 1883	44	1.25	1.25	......	31.50	28.00	......	......	18.90	......	......	......	......	......	......	......	......	Do.
May 2, 1883	45	1.00	.50	......	31.50	27.50	......	......	20.10	......	......	......	......	......	......	......	......	Do.
May 3, 1883	46	.50	.50	......	32.75	26.50	......	......	20.30	......	......	......	......	......	......	......	......	Do.
January 18, 1883	47	Trace.	.40	......	35.00	36.00	......	......	14.00	......	......	......	......	......	......	......	......	Do.
February 23, 1884	48	1.25	.50	......	31.75	31.37	......	......	16.40	......	......	......	......	4.53	......	......	......	Do.
	49	.50	1.00	......	33.00	14.22	......	......	13.10	25.78	4.20	1.00	......	......	......	......	91.30	Do.
	50	Trace.	1.40	......	29.60	11.56	......	......	7.50	43.25	6.34	Trace.	......	......	......	......	98.25	Do.
February 23, 1884	51	.80	.50	......	35.75	31.24	......	......	16.20	......	......	......	......	......	......	......	......	Do.
March 5, 1884	52	1.60	.80	......	36.25	31.10	......	......	17.90	3.61	......	......	......	......	......	......	......	Do.
October 2, 1882	53	.05	.90	......	33.50	31.90	......	......	17.90	......	......	......	......	......	......	......	......	Do.
March 13, 1884	54	Trace.	.70	......	33.80	34.20	......	......	19.25	3.47	......	......	......	......	......	......	......	Do.
March 17, 1884	55	1.20	.70	......	33.80	30.20	......	......	20.75	4.14	......	......	......	......	......	......	......	Do.
March 19, 1884	56	1.90	.70	......	34.00	29.96	......	......	20.80	3.99	......	......	......	......	......	......	......	Do.
March 21, 1884	57	1.50	.70	......	34.40	29.83	......	......	19.80	3.89	......	......	......	......	......	......	......	Do.
March 24, 1884	58	1.20	.50	......	34.25	32.80	......	......	17.10	3.45	......	......	......	......	......	......	......	Do.
April 3, 1884	59	1.70	1.10	......	33.85	29.90	......	......	19.90	3.51	......	......	......	......	......	......	......	Do.
April 7, 1884	60	1.30	.50	......	33.20	30.34	......	......	20.60	3.50	......	......	......	......	......	......	......	Do.
April 9, 1884	61	.80	.70	......	33.10	30.09	......	......	19.80	4.75	......	......	......	......	......	......	......	Do.
April 11, 1884	62	1.10	.50	......	31.85	32.98	......	......	20.65	4.54	......	......	......	......	......	......	......	Do.
April 14, 1884	63	1.05	.40	......	31.95	30.90	......	......	22.75	3.22	......	......	......	......	......	......	......	W. T. Page. 135-oz. bullion.
April 15, 1884	64	.45	.50	......	33.00	28.93	......	......	23.65	3.42	......	......	......	......	......	......	......	W. T. Page. 138-oz. bullion.
April 18, 1884	65	.50	.70	......	32.90	29.11	......	......	22.00	2.86	......	......	......	......	......	......	......	W. T. Page. 160-oz. bullion.
April 22, 1884	66	.60	.50	......	33.00	26.89	......	......	23.95	3.00	......	......	......	......	......	......	......	W. T. Page.
April 28, 1884	67	1.40	.60	......	33.20	27.51	......	......	24.00	......	......	......	......	......	......	......	......	Do.
March 5, 1884	68	.50	.60	......	34.60	30.09	......	......	22.00	2.97	......	......	......	......	......	......	......	Do.
	69	......	......	......	36.00	32.00	......	......	25.60	......	......	......	......	......	......	......	......	H. T. V. Furman. Pectolitic, fibrous.
	70	......	......	......	32.00	36.47	......	......	24.23		......	......	......	......	......	......	......	H. T. V. Furman. Fine translucent crystals.
	71	......	......	......	27.60	45.00	......	......	20.64	......	......	......	......	......	......	......	......	H. T. V. Furman. No lead found.
	72	......	......	......	29.80	39.50	......	......	19.30	......	......	......	......	......	......	......	......	H. T. V. Furman. "Old German slag."

Analyses of argentiferous lead slags—Continued.

Date.	Number.	Fire assay.		Specific gravity.	SiO₂.	FeO.	Fe₂O₃.	=Fe.	CaO.	MnO.	Al₂O₃.	MgO.	PbO.	ZnO.	PbS.	S.	Total.	Analyst and remarks.
		Ounces Ag.	Per cent. Pb.															
	73	......	......	......	31.00	34.83	......	......	24.10	......	......	......	......	......	......	......	......	H. T. V. Furman. Tetragonal crystals.
	74	......	......	......	32.20	28.50	......	......	27.50	......	......	......	......	......	......	......	......	H. T. V. Furman. Almost cubes.
	75	......	......	......	25.50	40.97	......	......	16.00	......	......	......	2.70	7.62	......	......	......	H. T. V. Furman. Aluminous.
	76	......	......	......	35.80	25.50	......	......	29.50	.60	3.90	......	1.36	......	......	......	......	H. T. V. Furman. Ran free.
	77	......	......	......	37.60	20.07	......	......	29.23	.41	5.50	......	4.68	......	......	......	......	H. T. V. Furman.
	78	......	......	......	36.20	26.20	......	......	30.00	......	......	......	......	......	......	......	......	Do.
	79	......	......	......	32.20	27.70	......	......	25.20	......	......	......	......	6.05	......	......	......	Do.
	80	......	......	......	35.80	23.74	......	......	28.20	......	6.65	......	......	......	......	......	......	Do.
	81	......	......	......	39.00	22.30	......	......	29.84	......	......	......	......	......	......	......	......	H. T. V. Furman. Very bad. Furnace closed.
February, 1884	82	.35	*a*.88	......	36.20	24.17	......	......	18.75	9.41	3.95	0	.88	4.67	......	.83	98.86	W. T. Page. Resembles porcelain.
February 1, 1884	83	1.50	.30	......	34.00	33.43	......	......	16.60	......	......	......	......	......	......	......	......	W. T. Page. 185-oz. bullion.
January, 1884	84	.20	.25	......	32.50	29.06	......	......	28.50	.23	2.71	0	......	3.60	......	1.15	97.75	W. T. Page. 70-oz. bullion. Monoclinic crystals.
February, 1884	85	1.00	1.10	......	37.70	35.48	......	......	14.00	7.48	......	......	......	......	......	......	......	
	86	1.50	1.20	......	35.30	35.35	......	......	18.00	3.87	......	......	......	......	......	......	......	
	87	.60	1.80	......	37.00	36.38	......	......	13.50	8.39	......	......	......	......	......	......	......	
	88	.90	1.30	......	38.20	32.52	......	......	17.70	5.80	......	......	......	......	......	......	......	
April, 1884	89	1.40	1.60	......	36.50	38.57	......	......	15.00	7.20	......	......	......	......	......	......	......	
	90	3.00	2.80	......	37.50	41.65	......	......	5.30	10.30	......	......	......	......	......	......	......	Old Leadville slag.
	91	.60	1.00	......	31.50	41.52	......	......	16.50	6.07	......	......	......	......	......	......	......	
	92	.60	.90	......	33.80	36.22	......	......	15.90	8.52	......	......	......	......	......	......	......	
	93	.80	.60	......	35.70	38.95	......	......	15.40	5.54	......	......	......	......	......	......	......	
	94	.50	1.00	......	32.60	36.80	......	......	16.60	4.00	......	......	......	......	......	......	......	
	95	1.25	1.50	......	34.60	41.80	......	......	15.10	4.00	......	......	......	......	......	......	......	
	96	1.25	1.50	......	34.90	35.70	......	......	15.00	......	......	......	......	......	......	......	......	
	97	5.00	3.00	......	40.00	17.70	......	......	22.30	......	......	......	......	......	......	......	......	Three hours after "blowing in."
	98	1.20	2.10	......	38.00	27.60	......	......	11.30	......	......	......	......	......	......	......	......	
	99	......	......	......	33.00	40.00	......	......	16.00	......	......	......	......	......	......	......	......	Type for impure ores—*A*.
	100	......	......	......	33.00	33.00	......	......	23.00	......	......	......	......	......	......	......	......	Type for impure ores—*B*.

a By wet analysis.

Types.—By the term "slag types" are meant those slags which are built up according to some well defined composition, and which always have a distinct crystalline form. Many of these types approach in composition certain well known siliceous minerals. It is somewhat rare to find in the same piece or pot of slag more than a single kind or type, though such cases will occur occasionally when there is a marked change in the ore charge, or where there is fed into the furnace a slag different in composition from that produced by the ore and lime flux. I have studied slags, with no small amount of care and attention, through the following wide ranges of composition:

	Per cent.
SiO_2	26 to 41
Fe	18 to 45
CaO	5 to 35
Mn	Trace to 40
MgO	Trace to 8

While it is possible, and even probable, that there may be some particular kind or class of slags which has escaped observation, the following types will include practically every known slag which is well adapted for argentiferous lead smelting:

Types of lead slags.

Type.	Percentage.		
	CaO.	FeO+MnO.	SiO_2.
A	6	52	32
B	10	45	35
C	12	50	28
D	16	34	34
E	20	40	30
F	24	33	33
G	28	27	35

It must not be understood that these types are rigidly fixed, since all of them are subject to certain ranges or limits, and still may be quite fair slags. Some, it has been noticed, are subject to wider limits than others; this is particularly true of the type F. By observation and long experience it has been found that slags of a certain kind are easily fusible, run freely, prevent certain mechanical difficulties in the crucible, and admit of long campaigns. These slags occasion small silver and lead losses and are therefore to be imitated as nearly as practicable; but to say that a certain slag is good or bad if the type is not accurately obtained is certainly erroneous. Where the type is so clearly approached that there occur certain slight alterations in the crystalline form, the slag may be, and generally is, a very good one to make; now to alter the slag so that the type may be more closely approached will sometimes be highly impolitic from a commercial standpoint. If, in short, we alter a slag which already closely approaches a given type, the cost should be an important item in the consideration, and not the beauty of the crystals.

I have noticed that most slags produced *between* certain recognized types assume a distinct appearance which more or less resembles that of the minerals pectolite and wavellite. Slags having a structure closely resembling these minerals may be designated as pectolitic or wavellitic slags. From what has been said it will be seen that all pectolitic and wavellitic slags may be regarded as abnormal. Generally pectolitic and wavellitic slags run high, that is to say, carry too much lead and silver, especially the latter, yet a very few exceptions to this statement have been noted where manganese enters largely into the composition.

There are a few well defined crystalline slags which are not adapted to lead smelting; this is particularly the case where the percentage of iron is very high and that of lime is low (see type A, Fig. 5 *a*, and analyses Nos. 1, 2, 3, 4, and 6).

All of the above named various types have been made by the writer, and run for some time, except the type A, which it is thought should only be used under exceedingly peculiar circumstances. It must certainly occasion much loss in both lead and silver, and aside from its being an expensive slag where siliceous ores are treated, it is also a dangerous slag to use, owing to the liability of forming "iron sows." It is thought best never to allow the percentage of lime to drop below 10 per cent.

Type B will keep the furnace in good condition and the tonnage large, but the silver and lead losses are also liable to be large. This character of slag is illustrated by analyses 12 and 17 and Fig. 5 *a′*. The crystals are generally small rhombic plates, more or less thickened, and are often hopper-shaped, and are characterized by well defined striations. There are conditions which make this an exceedingly economical slag. Where good limestone is not readily obtained at reasonable rates this is not a bad slag to make.

Type C, according to Dr. O. H. Hahn, has the formula: $6FeO\ 3SiO_2 + 2CaO\ SiO_2$; hence the following percentage of composition:

	Per cent.
SiO_2	30.61
FeO	55.10
CaO	14.29
	100.00

Now, by deducting 10 per cent. as an allowance for the other ingredients, there remain—

	Per cent.
SiO_2	27.55
FeO	49.59
CaO	12.86
	90.00

We therefore see that the slag belongs to the type C. This slag has been accurately described by Dr. O. H. Hahn in the "Mineral Resources of the United States" for 1882. The salient features may be briefly stated as follows: "The proportion of calcic oxide is to the ferrous oxide as 1: 4;" it has a marked physical appearance, a distinct crystalline form, color black, "frequently with a rusty brown film, and a fibrous texture;" it is a good slag, both commercially and metallurgically. It is not as free from lead as type E, "and is especially adapted for smelting ores containing a large percentage of zinc." It will be readily seen that where exceedingly siliceous ores are treated, which also contain much zinc, type C cannot be regarded as an economical slag; while in localities where iron flux is abundant and the ores carry much zinc, this slag cannot be too highly recommended.

Type D is well adapted to the treatment of siliceous and very impure ores; it crystallizes in the form shown in Fig. 5 *b*, and corresponds to the formula: $5FeO\ 4SiO_2 + 3CaO\ 2SiO_2$. This gives as its percentage of composition:

	Per cent.
SiO_2	40.54
FeO	40.54
CaO	18.92
	100.00

It was found that by smelting a certain class of ores, the united percentages of Si_2O, FeO, and CaO, as shown by analysis, would be 84; therefore, if we deduct 16 per cent. from each of the above given percentages, there would result—

	Per cent.
SiO_2	34.06
FeO	34.06
CaO	15.90
	84.02

or practically—

	Per cent.
SiO_2	34.00
FeO	34.00
CaO	16.00
	84.00

It cannot be said that the type D is the same as type F, which it closely resembles in chemical composition, since the crystalline form (Fig. 5 *b*) and physical properties are entirely dissimilar. Very excellent results have been obtained with this slag, even when producing high-grade silver bullion. The crystals of this slag are more or less translucent, flattened, and often contain an abrupt arrow-shaped point or termination. These crystals should not for a moment be confounded with the sharp, blunt, spear-headed slag formation which is due to a marked deficiency in iron (or manganese), since the latter slag invariably contains considerable silver. The chief objection to the type D is the difficulty of obtaining it. When there is a scarcity of both iron and lime, and siliceous ores must be treated, I know of no better slag than that given by type D; these slags will invariably run very low in lead, and the silver will vary from half an ounce to two-and-a-half ounces per ton, according to the grade of bullion and the lead charge.

Type E is a most excellent slag; it is a true singulo-silicate, and has the formula: $6FeO, 3SiO_2 + 4CaO, 2SiO_2$. This gives as the percentage composition:

	Per cent.
SiO_2	31.38
FeO	45.18
CaO	23.44
	100.00

By deducting 10 per cent. as an allowance for other ingredients we would obtain:

	Per cent.
SiO_2	28.24
FeO	40.66
CaO	21.10
	90.00

It is customary to carry at least 30 per cent. SiO_2 in forming this type of slag. The CaO : FeO practically as 1 : 2; the physical properties are well marked, and it crystallizes as shown in Fig. 5 *c*.

"If," says Dr. Hahn, "the proper amount of fuel has been given to the charge, it will contain neither lead nor silver; and it is my opinion that if it ever is metalliferous it is through small globules of matte dissolved in it, which have not been separated on account of lack of heat in the furnace. Running on such a slag a furnace can never get out of order except through gross carelessness." I have previously stated that *all* lead slags contain at least *some* lead and silver, although the amounts may be small, perhaps merely a trace; yet I have never seen a slag which at the same time contained only a trace of lead and silver, although I have examined a very large number of slags which were claimed to be free from these elements. This slag is used to "blow in" a furnace, to loosen up crucible obstructions, and also immediately after "barring" the furnace hangings, with markedly good results. It allows a large tonnage, requires a comparatively small amount of fuel, and is in short an economical slag where it can be continuously run, but in certain localities where iron flux is quite scarce, it is not as profitable a slag as the types D, F, and G.

Type F is the next well defined slag in the lime scale (see Fig. 5 *d*, and analyses Nos. 63, 64, 65, 66, 67, 68, and 84). The most perfect crystals I have noticed belonging to this type were carefully analyzed, giving the results as stated in analysis No. 84. This is a black, lustrous slag, distinctly resinous. The crystals are rectangular prisms, remarkably translucent, and in fact where there is little manganese present they are often transparent; the tops of a number of the crystals are slightly indented or hollowed out, like salt crystals. It is an exceedingly friable slag; the powder is mouse-colored. I am indebted to Mr. H. V. Furman for a specimen of this slag; to Mr. A. F. Schneider is due the discovery of the type. This slag contained only two-tenths of an ounce silver and one-quarter of one per cent. lead, and is the freest from lead and silver of any slag I have ever been able to find.

Type G is perhaps the best slag which has been discovered for the treatment of exceedingly siliceous ores. Mr. Raht, metallurgist of the Horn Silver works, Utah, produced this slag with most excellent results, working ores containing considerable baryta, alumina, and zinc. If I am properly informed, Mr. Raht is the discoverer of this most excellent type, which first gained publicity through an article by Mr. Schneider. This slag crystallizes in the form shown in Fig. 5 *e*, and will usually contain from 25 to 30 per cent. CaO. The pectolitic forms of these high lime slags are sometimes good.

The slag crystallizing in hexagonal plates, as shown in Fig. 5 *g*, is sometimes good, but more often these indicate a bad slag according to my own experience. These hexagonal plates may be regarded as indicative of too high a percentage of lime, in forming the high lime slags. In attempting to flux exceedingly siliceous ores with lime alone, we will obtain slag appearances like Fig. 5 *f*, *f′*, and *h*. But while such slags (notably Fig. 5 *f′*) are remarkably free from lead, the silver is alarmingly high; according to the experience of others, however, the very reverse has been observed. In making this high lime slag, where there is a great deficit in either iron or manganese, the fuel and the lead charge have little or no effect in reducing the silver losses.

In conclusion it should be said that there is unmistakably some law governing the losses of both lead and silver in lead smelting. This law, it seems to me, has never as yet been clearly enunciated. We know that most highly crystalline slags are good, yet some slags which have no well defined crystalline form are also good. Furthermore, it is known that most easily fusible and fluid slags are good, and yet this is not always the case. Why should one slag be good and another be bad? To say that there should be a certain ratio existing between the silica and the bases does not solve the problem. The fuel also has a very important bearing upon this question, and it is well known that coke alone will produce a cleaner slag than a mixture of coke and charcoal. While the use of charcoal will give an increased tonnage, it will also generally cause an increased loss in silver.

The dissemination of matte globules in the slag does not to my mind satisfactorily explain the silver losses, since I have detached perfectly pure crystals from the very heart of the pot from slags of all of the above given types, and as a general thing these crystals were found to contain a larger amount of silver than the main body of the slag; the lead contents will usually be less. It was once thought that silver losses were due largely to manganese by the formation of silicate of silver (that is, the nascent oxygen given off from the manganese oxides would oxidize the silver, and this would unite with silica and thereby be carried off into the slag). I have elsewhere shown the impossibility of this supposition, and that there is no good ground for believing that such a compound has ever been produced or can be.

Can it be possible that the amount of cyanogen existing in the furnace at different times when producing certain types of slag has any bearing upon this subject? Aside from the fact that there are certain well known ratios which should exist between the silica and the bases present (for example, iron and manganese), and that lime has a most remarkable influence in cleansing the slag, we know little or nothing regarding this subject.

There seems to be some law governing the crystalline form and the amount of lime present, and it has been noticed that slags having different amounts of lime usually crystallize as follows (see page 441):

Slags having 3 to 5 per cent. CaO crystallize like Fig. 5 *a*.
Slags having 8 to 12 per cent. CaO crystallize like Fig. 5 *a′*.
Slags having 15 to 18 per cent. CaO crystallize like Fig. 5 *b*.
Slags having 19 to 22 per cent. CaO crystallize like Fig. 5 *c*.
Slags having 23 to 25 per cent. CaO crystallize like Fig. 5 *d*.
Slags having 25 to 27 per cent. CaO crystallize like Fig. 5 *e*.
Slags having 30 to 35 per cent. CaO crystallize like Fig. 5 *g*.

And, finally, two slags which have almost the same identical chemical composition will frequently give by assay very dissimilar results.

RECENT IMPROVEMENTS IN DESILVERIZING LEAD IN THE UNITED STATES.

By H. O. Hofman.

The process employed in all the desilverizing works in the United States but one for extracting silver and gold from base bullion is that invented by Parkes. It is based upon the fact that zinc has a strong tendency to alloy with gold and silver, and a comparatively slight one to alloy with lead. Thus when zinc is added to molten lead containing the precious metals, the latter will be separated from the lead and form an alloy with the zinc, from which the pure metals can be extracted with comparative ease.

The Rozan process (a modification of Pattinson's process), which is in use only at the Richmond works, Eureka, Nevada, and the desilverization of lead by electrolysis (see "Mineral Resources of the United States, 1882," page 650), on which Mr. N. S. Keith is experimenting at Rome, New York, will not be discussed in this paper, which will be confined exclusively to desilverizing by zinc as it is carried on in the principal refineries of the United States.

There have been nineteen refining works built in the United States within the past fifteen or twenty years. Of these eight have either stopped working altogether or are refining only at intervals on a small scale. The works in actual operation are those at Omaha, Nebraska; Kansas City and Saint Louis, Missouri; Aurora and Chicago, Illinois; Mansfield, Pennsylvania; Newark, New Jersey; the Selby Works at San

Francisco; the Richmond Works at Eureka, Nevada; the Germania Works at Salt Lake City, Utah; and the Pueblo Works at Pueblo, Colorado.

The arrangement of the different parts of the plant of a refinery must of course vary somewhat according to its location, but a certain sequence of apparatus inheres in the nature of the process. Its general order may be briefly stated as follows: On the highest level will be the softening furnaces, which receive the base bullion and prepare it for the kettles. The latter are a stage lower, and here the softened bullion is desilverized. The apparatus for liquating the zinc crusts is also upon the same floor, and a track leads from it to the tops of the bins which hold the liquated crusts ready for distillation in the retort room. This lies on the same level as the cupelling room, where the retort bullion is turned into fine silver or doré silver bars. Following the desilverized lead we reach the next level, that of the refining furnaces in which the desilverized lead is dezincified. Thence it passes, according to the method of working in use, either at once into the molding apparatus on the same floor or into another kettle, and from this to a lower level, where it is cast into molds and shipped.

The working of by-products varies in different refineries according to their location and to the mode of working (whether with reverberatory or blast-furnaces). It also depends largely upon whether ore smelting is carried on to any extent or not at the same works. Thus we have:

1. Receiving and assaying base bullion.
2. Softening base bullion.
3. Desilverization of softened bullion.
4. Dezincification of desilverized lead.
5. Molding of refined lead.
6. Treatment of zinc crusts.
7. Cupellation of retort bullion.
8. Treatment of by-products—softening dross and skimmings, kettle dross, refining skimmings and polings, retort dross and blue powder, litharge, old retorts, cupel bottoms, etc.

Receiving and assaying base bullion.—The handling of the bullion till it is ready to be softened (that is, unloading, weighing, and sampling) has been much simplified and improved. The base bullion usually arrives from the West in carloads of 10 short tons each, and the following is one of the best and easiest ways of handling it: The track on which the railroad cars carrying the base bullion are to arrive is laid so low that the bottom of the car is on a level with the upper platform of the works. Along the whole length of this platform and parallel with the railroad runs a narrow-gauge track bearing a number of strongly built bullion trucks. At one or two points upon the track are scales, on which the bullion is weighed. It is carried out from the car, loaded upon the truck standing before the car door, and when this is filled to a height convenient for lifting (about 3½ feet) it is moved on and another takes its place. The trucks are run on the scales, the bullion is weighed, and is then sampled from them directly on to other trucks. These last move straight to the softening furnaces or to places near them, and no more handling is required before the bullion is charged into the furnaces.

In the department of sampling and assaying there has been much disputing between smelters and refiners, whose results often differ considerably. Impressed with the importance of finding a method of sampling that should approximate closely to the real average of assays, the writer three years ago went to work in the following way: He first obtained the actual exact assay by cutting bars of bullion into three pieces, taking samples systematically from each piece, numbering these and assaying them separately. Having thus arrived at the most careful results, various experimental methods of sampling were tried, and the following was found to be the best. It comes very close to the actual average, and is often identical with it: Punch samples are taken diagonally across a row of, say, five bars, driving the punch every time deeper than half way through; the bars are then turned over, and this is repeated on the other side in the opposite diagonal.

The samples are now usually melted down in a crucible that has been well heated for some time, so that the melting can be accomplished quickly. When the mass has come to a red heat, so that the dross is about dissolved, but no cupelling has begun, the lead is well stirred for not less than five minutes, and is then poured, with the dross, into a mold of, say, 3 by 7 inches. This sample bar, representing 10 short tons of base bullion, ought to weigh about 8 pounds avoirdupois, and rather more than less.

Different works have now different modes of procedure. The following is perhaps the most satisfactory: Four samples of somewhat over one assay ton each are taken from the middle of the four sides of the sample bar, cutting the entire bar through. From these, four samples, of exactly one assay ton each, are weighed out and cupelled. The results from using one assay ton for cupellation have been more satisfactory with the silver as regards accuracy and uniformity than when half an assay ton was taken. The reason for this is manifest, the chances of possible inaccuracy being diminished one-half. Of course with gold, especially if the bullion contains only traces of it, we have also the advantage (from using 4 assay tons instead of 2) of the added weight.

Softening base bullion.—Base bullion as it comes from the smelter is more or less contaminated with impurities (as copper, sulphur, antimony, arsenic, etc.). These have to be removed before the desilverizing can be successfully accomplished. It is usually done in a reverberatory furnace, called a softening furnace.

The bed consists of a pan which is made either of cast iron or wrought iron, preferably the latter. This rests upon transverse rails, and they in their turn upon brick walls, which extend longitudinally. The hearth is built into the pan. It is dish-shaped in section and elliptical in plan. In depth it should be not more than 10 or 11 inches, the other dimensions varying according to the desired capacity, its length being usually to the breadth as 1½ to 1. If the pan is made of cast iron, it must stand free, as pressure from the roof of the furnace would increase its tendency to crack. This it is liable to do in any case. If, on the other hand, the pan is made of wrought iron, these precautions are unnecessary, the roof resting upon angle iron, which acts not only for support but also to prevent the hearth from rising. This is the best method of construction and also the cheapest. The hearth is usually made as follows: First, a layer of brasque is carefully tamped in and then so cut out that the course of firebrick which is to be laid endwise upon it shall bring it to the desired shape. The walls are built in the same way, the entire inside surface consisting first of brasque and then of brick. Some furnaces dispense with brasque for the sides, and substitute a course of red brick. The entire hearth has an inclination toward the tapping hole, which is either on the same side as the flue or opposite the charging door. The latter arrangement takes up less room than the other, and is therefore to be preferred. If the pan is of cast iron a spout is screwed on it, and the opening is closed by tamping in a small breast. If wrought iron is used, a cast-iron pipe extends outward along the bottom of the hearth and is fastened with bolts to the pan, the opening in the side wall through which it passes being carefully filled with hard beaten brasque. It is opened and closed with a clamp and thumbscrew or a slide valve.

The bullion is charged through a side door by means of a long-handled paddle, running on a roller. The lead is then melted down with a low heat. When melted, it is stirred, heated again, and the furnace-dross (a mixture of lead, copper, sulphur, etc.), is raked or skimmed off. The heat is then increased and the furnace is kept red hot till all the antimony and arsenic are oxidized and combined with protoxide of lead into antimoniate and arseniate of lead; the furnace is then cooled and these softening skimmings are removed. The process of softening is apt to be a lengthy one, especially if much arsenic is present. One mode of hastening it is to cool repeatedly and skim off the crusts as fast as formed. This gives an ever fresh surface for oxidation, which can be increased in two ways—first, by artificial blast entering at each side of the fire bridge, and secondly, by steam introduced through pipes pressed down lengthwise into the lead. The former method has not been eminently successful, but the steam pipes are found to work very effectively by stirring up the lead so that it constantly presents new surfaces for oxidation. One disadvantage, however, arising from it is the constant washing of the hot lead and litharge against the sides of the furnace. This rapidly corrodes and destroys the brick. As a protection, pipes, in which water circulates, have been introduced behind the brickwork at the level where it meets the upper surface of the lead. These have proved very helpful. It must also be added that a repeated cooling of the surface of the lead retards its actual softening. Perhaps the best way of averaging the difficulties and producing the most satisfactory results is to mix hard and soft bullion in the charge, cool and skim once only (unless absolutely necessary), and take special care that the hearth is not too deep, introducing the steam pipes as a last resort.

The method occasionally employed of softening in kettles by the aid of steam or compressed air is an expensive and slow operation, inferior in all ways to the other.

Many efforts have been made to reduce the consumption of fuel, and generally with small success. It appears to the writer that every refinery which works steadily should be provided with gas furnaces. The softening, refining, and cupelling furnaces need a strong oxidizing flame. The kettles must be alternately heated and cooled as fast as possible, while in all departments a good even heat is much to be desired. All these requirements would be better met by gas than by any other form of fuel, and it is confidently believed that the ultimate expense would prove less than at present.

Desilverization of softened bullion.—From the softening furnaces the bullion is run off through troughs into desilverizing kettles. These are spherical in form and have each a separate fireplace and chimney, the products of combustion passing first around the kettle through a circular flue beneath the brim. The kettles are usually 3 feet deep, with a diameter which varies according to need, the original capacity of 10 short tons having been gradually increased, with complete success, to 40 tons. The kettles are tapped either by a discharge pipe running out from the bottom or by a siphon. In the former case the pipe is closed by a slide valve on the outside of the kettles or by a clamp and thumbscrew within it. The objection to the pipe is, first, the additional expense, and, secondly, the difficulty of keeping it tight if the kettle has been in use for some time. Then also a certain amount of undesilverized lead will be lost with the outside slide valve through the discharge pipe, and if a thumbscrew within the kettle is substituted, the rod will always be in the way. To empty the kettles by use of the siphon is a simple and elegant method, preferable in all respects to the other, and easily learned with a little practice. The siphon is made of gas pipe and the section arm has a cock at the lower end. The pipe is heated and filled by putting it into the full kettle; the cock is then closed and the longer arm taken out and suspended, the shorter one being held down in the lead. When the cock is opened the lead runs out.

The desilverizing process proper is as follows: After being heated the kettles are filled from the softening furnaces and the dross (kettle dross) is skimmed off from the surface of the lead. The first addition of zinc is then made, the quantity depending upon the amount of gold and copper in the kettle. When the zinc is melted it is stirred into the lead. This stirring in has always been a hard task for the workman, and various mechanical stirrers have been used, but the hand stirring was found best, until stirring by steam was successfully tried. An inch pipe is inserted in the middle of the kettle 12 inches deep into the lead, and dry steam is passed through it. This stirs as evenly and thoroughly as could be desired. The fire beneath the kettle is now removed or banked up (preferably the latter) and the kettle is allowed to cool. This cooling has been sometimes hastened by the use of a pipe in which water circulates, but the results are not very satisfactory. The gold crust (an alloy of lead, zinc, copper, gold, and silver) now rises to the surface, and is collected by skimming with a perforated ladle. The use of this ladle is made much easier by a hook suspended on a chain, which acts as a lever, and is of great assistance with the heavy crusts which form in the desilverizing kettles holding 36 or 40 net tons of soft bullion. Any alloy adhering to the sides of the kettle is now removed by scraping with a chisel-pointed bar, and skimming and scraping are continued until no more crusts appear. All the gold being removed (this is ascertained by assay), the kettle is reheated and the same operation is repeated to extract the silver. It is usually repeated three times, and is discontinued when 0.2 ounce or less of silver to the ton remains. If the assay shows more than this, the use of steam will again be found effective in taking another crust from the kettle. Its introduction for half or three-quarters of an hour will invariably reduce the silver contents of the kettle and thereby often save an entire zincing.

As the desilverizing requires more time than the softening or refining it becomes the standard by which these other operations must be regulated. Thus the proper rotation is preserved and no time is wasted. If the capacity of the kettles be enlarged the proportion of lead desilverized within a given time is greatly increased (as 40 net tons in 24 hours instead of 25 tons in 20 hours) with very little additional outlay.

Of course after each separate operation the weight and value of main product and by-product are accurately determined and the results noted for future reference.

In assaying after the removal of the gold crust the object will be, first, to find whether all the gold has been removed, and, secondly, how much silver has been taken off with it. One assay ton shows no gold; with four it appears slightly, and if the buttons of 8 assay tons are dissolved a weighable amount of gold will be found. Thus, although the gold has a stronger affinity for zinc than the silver, it is not easy to remove it altogether. It would therefore seem to be still an open question whether it is not more profitable to make doré bullion alone by taking out the precious metals with two or three zincings than to make doré bullion and fine silver by four, five, or even six additions of zinc.

Dezincification of desilverized lead.—The general construction of the refining furnace is the same as that of the softening furnace. In capacity it compares with it about as 5 : 6. Nothing requires special mention except the tapping. If the last traces of antimony and arsenic are to be removed, as is sometimes done, by poling with steam, the lead is tapped off from the refining furnace into a kettle, just as the bullion is from the softening furnace. This will also be done if the molds are to be filled either by hand or by the use of a siphon. A better way, however, is to tap directly from the refining furnace into the molds. This requires, first, a piece of gas pipe screwed into the pan, which must either be cast thick enough for a thread to be cut in it or (if wrought iron) be strengthened with flanges and fastened by bolts, both inside and outside. The pipe is joined by a cock to a **T**, whose horizontal arm is closed with a plug. At the vertical end of the **T** a horizontal pipe with an elbow is attached. The method of tapping directly from the refining furnace by aid of this simple apparatus is unquestionably to be preferred to any other. In the operation itself the remarks under the head of "Softening" are generally applicable, with this addendum : The use of steam to hasten oxidation by mechanical agitation has a new advantage in the refining furnace, as it also acts chemically in oxidizing the zinc.

Although in refining the reverbatory furnace is almost exclusively used, we sometimes find it replaced by a kettle. With the aid of steam this can be made to produce as fine a lead as the reverbatory furnace, and the by-products of zinc oxide and lead oxide which result have often considerable market value. It must also be confessed that the kettles, if of the best quality, last longer than is generally supposed, and do not corrode as rapidly as those used in place of the softening furnace.

Molding of refined lead.—This can be accomplished by hand, by use of a siphon, or by the apparatus described above. The first method is antiquated and has passed into disuse. The second (with a siphon) is, like the first, done from a kettle, the molds being placed on a lower level, where the bars are also stamped, weighed, and shipped. The siphon is precisely like the one used to empty the desilverizing kettles, with the addition of a movable pipe of the same length as the long arm of the siphon and so attached to it that it can swing either vertically or horizontally. Below upon a double track run trucks on which the molds are placed in rows. These pass along and receive the lead. Their rotation is so managed that while the second one is filling the first one switches off to the other track. Here it is out of the way and can cool and unload while the second and third are filling. Thus three trucks with molds are indispensable, while four is the number in general use. The siphon has this disadvantage, that it cannot be stopped and started again until the charge is entirely emptied. With the third method (the apparatus of gas pipe, etc., attached directly to the refining furnace) the trucks are also used, unless (which is the better way) the end pipe is made to swing freely by attaching it to the **T** with a nipple. With this the lead can be discharged directly into molds placed upon the same floor in a semicircle having its center beneath the vertical arm of the T. The pipe moves around horizontally, filling them each in turn. This method is not only a saving of trouble, but the bars are much smoother and more shapely, if not moved until the metal has completely hardened. Before using the pipe apparatus a fire is kindled beneath the cock to melt any lead that may have solidified there, and the discharge pipe is detached and heated in the refining furnace.

Treatment of zinc crusts.—When the zinc crusts (containing gold and silver) are skimmed off the desilverizing kettles an excess of lead is also carried away with them. This has to be removed by liquation, the gold and silver being separately liquated, before the crusts go into the retorts to be distilled. Liquating was formerly done in small kettles of varying shapes and depths. These have all gradually given way to a shallow kettle of medium size having a discharge spout through which the liquated lead runs off into a small spherical kettle. It is then put back into the desilverizing kettle and forms a part of the next charge. The liquation pot is usually placed on a level with this last and close beside it, the smaller kettle for the liquated lead being on a level with the working floor of the desilverizing kettle. The crusts are heated to a dull red heat, so that they may become as dry as possible, and are then taken off with perforated ladles and raked out upon the floor into convenient shape for the retort. The latest improvement consists in liquating the zinc crusts in a reverberatory furnace, to which is added the smaller kettle for liquated lead. This is a quicker operation than that in the kettle, and the crusts become drier and do not require to be raked afterwards, which is an advantage with large quantities.

According to the Flach process the dried zinc crusts were smelted in the blast furnace, but they are now treated altogether in retorts. These are uniformly made of graphite. Their capacity has been increased from 200 to 700 pounds. Both stationary and tilting retorts are in use. Of these the tilting retort heated by coke will stand about fourteen charges, while a stationary one, where the clinkers can be removed, will stand twenty-five. A stationary retort heated by coal will stand about twenty charges. The perishability of the retort is caused by the action of the lead inside and that of the fuel without. The latter has been diminished by giving the outside of the retort a coating which will frit but not melt, will be impervious to gases, and to which clinkers from coke will not adhere. This is found to preserve the retort considerably. The condenser is usually made of cast iron and all other forms have given way to the simple conical one.

About the operation itself there is not much to be said. The retorts, when hot, are charged with the dried crusts mixed with charcoal. As the mass melts down more is added until the retort is entirely full. The condenser is then attached, and in about eight or ten hours the distilled zinc has all run out or been tapped off from the condenser. The lead can then be tapped or ladled out. If the retort is a tilting one it can be simply poured off.

The retorting of zinc crusts is the weak point of the Parkes process. There is much room for improvement here. In Germany the Schnabel-Cordurié process, which is used at the Government silver works of Lautenthal, gives great satisfaction. It has two special advantages: First, that it converts all the zinc into marketable zinc white, and, second, that it diminishes the inevitable loss of silver. It has not yet been introduced in the United States.

Cupellation of retort bullion.—The silver in the retort bullion, which ought to average 3,000 ounces to the ton, is now subjected to the last process, that of cupelling.

The furnace universally used is the English cupelling furnace. It has undergone various changes in the test and in the manner of working, but it is also used in its original form. This retains the flat ring made of wrought iron, which in the modified form of the furnace has been replaced by a water jacket. At first this water jacket was made of a single piece of cast iron, later in sections, the original elliptical form being retained. The old method of fastening the test to the compass ring with wedges has given way entirely to the use of set screws. The latest water jackets are made square and are of copper, excepting the front piece, which is cast iron. This contains a channel for the litharge, and can be removed when it becomes corroded and another piece slipped into its place without stopping the furnace. The water-jacket test is used more for concentrating than for finishing. There are many ways of fastening the test, one of the best being to use transverse bars, upon which it is fixed with four set screws. An excellent method of support for the ordinary test is described, with drawing, by Mr. F. C. Blake in the "Transactions of the American Institute of Mining Engineers," Vol. X., the essential advantage being that it is movable in all directions while in operation. The back part is supported by two set screws, and towards the front two diverging arms are fastened. These are hooked with swivel screws to the base of a triangle, and the latter is attached to a differential pulley. With this pulley the test can be moved up or down to empty it, and with the swivel screws sideways to counteract the action of the litharge should this corrode one side of the hearth more than the other.

Bone ash as filling material for the test is little used nowadays, a mixture of clay and limestone or Portland cement being generally preferred. If the clay mixture is used, the test is tamped quite full and the cavity then scooped out; if cement, the test is tamped over a mold having the shape of the cavity. This has to be done quickly before the material sets. Tests filled with cement are more durable than those filled with the clay mixture.

The actual cupelling depends upon whether the concentration and finishing are to be done in the same furnace or not. For large production it is better to divide the work. If a furnace with a water jacket is used to concentrate the bullion to, say, 60 per cent. of silver, it can be run by an inexperienced man, while judgment and practice are necessary with a test where the litharge channel has to be regulated by the cupeller. Thus by dividing the cupelling into the two operations of concentrating and finishing, a smaller number of experienced and reliable cupellers is required. The original mode of producing blast by a steam jet has given way to the use of a blower. The cast-iron pot into which the litharge runs has lately in several places been superseded by a square wooden box containing water which circulates constantly through it. This has two advantages. It reduces the temperature for the cupeller and it presents the litharge in a granulated form which is easily handled and sampled. When the silver is fine, it is ladled out into molds, or (if the above cupel described by Mr. Blake is used) it is poured. The sample for assaying the silver is best taken in the following way: When the mold is filled with silver a heated spoon is inserted, the silver is stirred with it and a sample is taken and granulated. This gives very satisfactory results.

The separating of doré bullion, which is carried on in some refining works, must be considered as belonging to an entirely separate department and will not be more than mentioned here.

Treatment of by-products.—This is a very important part of the refining work. It requires to be carried on simultaneously with the main operations, so that the by-products may be disposed of at once and not allowed to accumulate. The blast furnace was formerly exclusively used in this department, but the reverberatory furnace has been found to be a valuable auxiliary. If ore smelting is done at the refining works the resulting slag will readily take up the zinc of the by-products. When no ore is smelted the same slag has to be used over and over and becomes so charged with zinc that it is apt to give trouble by clogging up the furnace and cause losses in silver and lead.

Softening-furnace dross and trimmings.—These are now usually first liquated in the reverberatory furnace with the aid of a reducing flame, that as much lead as possible may be extracted. The furnace has two tapholes, the lower one for the bullion and the upper for the skimmings. After the dross is liquated it is raked out through the furnace door. The liquated skimmings are tapped either into a pot or on to an iron plate. The latter way is preferable. The liquated dross is smelted in the blast furnace with some sulphur-bearing body (galena, etc.) to form a matte, which is then concentrated to about 40 per cent. of copper, when it is ready for shipping. The liquated skimmings are low enough in silver (1 or 2 ounces to the ton) to be smelted in the blast furnace (usually a separate small furnace). The ensuing hard lead is sold as such after having been poled at a low temperature in a kettle for several hours. Another way is to smelt the skimmings directly in the blast furnace and make a hard bullion. This is charged into the softening furnace with soft lead poor in silver (say Missouri lead), the silver in the original hard bullion being thereby reduced and the softening also facilitated. These softening skimmings are then smelted into marketable hard lead. This last runs higher in silver than that obtained from the other process, which runs about 2 ounces per ton.

Kettle dross.—The impurities contained in this dross are about the same as those of the furnace dross and skimmings. It is therefore usually put back into the softening furnace with the next charge, this being the most convenient way to dispose of it.

Refining skimmings and polings (*if any*) are worked best in a separate reverberatory furnace. Their principal contents being lead they are mixed with coal and the ensuing lead is worked into the next charge of the refining furnace or sold as a second-class lead. The residue, which contains lead, zinc, some antimony, and coal ash, is added to the smelting charge of liquated softening skimmings. The old way of smelting the original softening skimmings with refining skimmings and polings to reduce the silver contents has been abandoned, as has also that of putting the refining skimmings into the softening furnace, after the dross had been removed, with the idea that the antimony and the arsenic of the bullion to be softened would take the necessary lead from the skimmings and not from the bullion.

Retort dross and blue powder are very disagreeable by-products. The former is sure to carry off valuable silver, and the latter is very refractory, and has given rise to various modes of treatment. One of these is to mix the blue powder into the first zinc addition for the gold crust. This utilizes the metallic zinc in the powder and prevents the silver from being lost. Another way is to add it to the charge of the softening furnace, where the metallic zinc is burned off, the oxide being slagged off with the softening skimmings. It can also be worked off gradually with the charge in the blast furnace. This blue powder is the *bête noir* of the refinery, and ought not to appear in any considerable quantity if the retorting is properly done. The retort dross is usually worked off in the cupelling furnace, sometimes in the blast furnace.

Litharge.—This is reduced either in the blast furnace or in the reverberatory furnace, the latter being preferable unless the works carry on ore smelting. In this case the litharge is added to the ore charge.

Old retorts, cupel bottoms, etc., go into the blast furnace and are worked off with its products.

It will be seen from the foregoing sketch that the recent improvements in desilverizing base bullion have been rather in the line of practical adaptation and the working out of detail than in that of original scientific invention. The process remains to-day substantially the same that Mr. Parkes patented in 1850 and 1852, but its actual commercial value has greatly increased. To illustrate this, we have only to compare the results of former years with those of to-day, when large quantities of base bullion are desilverized with a simple apparatus, comparatively little manipulation, and a greatly reduced corps of men. Formerly it was considered necessary that each separate part of the apparatus should have one or two men to watch it, while now with contract work we have a plant for 25 net tons (softening, desilverizing, refining, and molding the lead ready for shipment), managed in twelve-hour shifts by a crew of three men, and a plant of 40 net tons by a crew of four. This improved distribution of work and general economizing of resources has been rendered possible by the help of the various new appliances and the methods described above. Many of these appear insignificant when taken singly, but each has its own special importance, and taken together they go to make up a general result of much practical significance.

ZINC.

THE ZINC INDUSTRY OF THE UNITED STATES.

By C. Kirchhoff, Jr.

The conditions affecting the zinc industry of the United States have not undergone any marked changes during the years 1883 and 1884. The circumstances influencing the producers of the East and the West are entirely unlike. In the West the new works built during 1881 and 1882 in Kansas and Missouri have sharply competed for ore on the one hand and have forced metal on the market on the other hand. The home producers have again obtained full control of the domestic market, the imports having dwindled down to insignificant figures. In spite of this, the supply has been too large as compared with a considerable falling off in the consumption. Taking into consideration the fact that in 1883 the imports were still large and the market was forced to absorb old stocks of imported metal, it is likely that in spite of the increase in the output in 1884, small as it was, the supply of spelter in that year was really smaller by about 2,000 to 3,000 tons. In the West strikes in the coal mines, flooding of zinc ore mines, and other troubles have contributed to embarass producers. On the whole the years 1883 and 1884 have weighed heavily on the industry.

No efforts have been made to extend the scope of inquiry, in view of the fact that the bare collection of the statistics needed improvement. The work has met with much more encouragement, but the returns are not yet so complete as to render some estimates unnecessary. The latter, however, affect only a few small southern works, the product of which could be got at independently with a close approximation to the correct figures. Every large concern in the eastern and western States has furnished the needed details, and the statistics submitted are at most 200 or 300 tons out of the way.

PRODUCTION.

The records of the production of spelter and zinc in the United States are very incomplete. The following figures are the only ones worthy of consideration which are available:

Production of spelter in the United States.

Years.	Short tons.	Years.	Short tons.
1873	7,343	1882	33,765
1875	15,833	1883	36,872
1880 (census year ending May 31)	23,239	1884	38,544

Zinc statistics are sometimes stated in pounds. For 1883 and 1884, the figures would be 73,744,000 and 77,088,000 pounds respectively. The production during the last five years may be segregated as follows, by States:

Production of spelter in the United States, 1881 *to* 1884, *inclusive, by States.*

States.	1881.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*
Illinois	16,250	18,201	16,792	17,594
Kansas	5,000	7,366	9,010	7,859
Missouri	2,750	2,500	5,730	5,230
Eastern and Southern States	(?)	5,698	5,340	7,861
Total	(?)	33,765	36,872	38,544

In addition to the output of metallic zinc there has been a considerable production of zinc white (oxide), made directly from the ore.

CAPACITY OF THE ZINC WORKS.

The following table gives the capacity of all the western zinc works and of some of those in the East. In many instances the number of retorts has been appended, but it should be distinctly stated that owing to the wide variations in their size and in their position in furnaces of different design they do not furnish any basis for a computation of capacity. Some of the works have not been running for some time; others are and have been running only at one half or three-quarter capacity at times.

Annual capacity of the western and some of the eastern zinc works.

Works.	June, 1883.	December, 1884.
ILLINOIS.	*Tons.*	*Tons.*
Collinsville and Lumaghi Zinc Works, O. F. Meister & Co., Collinsville (4 Belgian furnaces, 330 retorts)	800	1,000
Illinois Zinc Company, Peru (3 gas, 10 Belgian furnaces, 1,788 retorts)	7,200	8,000
Mathiessen & Hegeler Zinc Company, La Salle (4 double gas furnaces, about 3,200 retorts)	12,500	13,000
	20,500	22,000
MISSOURI.		
Missouri Zinc Company, Carondelet (14 Belgian furnaces) (*a*)	4,000	4,000
Glendale Zinc Company, Carondelet (8 Belgian furnaces)	3,000	3,000
Carondelet Zinc Company, Carondelet (4 Belgian furnaces)	1,000	1,000
Southwestern Lead and Zinc Company, Rich Hill (1 Belgian furnace, 1 Siemens furnace)	2,250	2,250
West Joplin Lead and Zinc Company, Joplin (6 Belgian furnaces)	2,250	2,250
	12,500	12,500
KANSAS.		
J. H. C. Gross, Weir City (8 Belgian furnaces, 896 retorts)	3,500	3,500
R. Lanyon & Co., Pittsburgh (8 Belgian furnaces, 784 retorts)	3,500	3,500
S. H. Lanyon & Bro., Pittsburgh (4 Belgian furnaces, 392 retorts)	1,500	1,500
M. & J. Lanyon, Pittsburgh (2 Belgian furnaces)	750	750
Granby Manufacturing and Smelting Company, Pittsburgh (1 Siemens furnace, 400 retorts)	1,250	1,250
	10,500	10,500

a Not running.

Annual capacity of the western and some of the eastern zinc works—Continued.

Works.	June, 1883.	December, 1884.
ARKANSAS.	*Tons.*	*Tons.*
American Zinc Company, White River (4 Belgian furnaces) (*a*)	1,000	....
Total capacity	44,500	....
EASTERN.		
Bergen Port Zinc Company, Bergen Port, New Jersey (8 Belgian furnaces, 888 retorts)	....	2,000
New Jersey Zinc and Iron Company (7 Belgian furnaces, 416 retorts)	....	1,137
Lehigh Zinc and Iron Company, Bethlehem, Pennsylvania (16 Belgian furnaces, 1,200 retorts)	....	6,000

a Has not been running for over two years.

The former Excelsior Concentrating and Smelting Works, at Collinsville, were leased by the Collinsville and Lumaghi Zinc Works (Messrs. O. F. Meister & Co.), May 1, 1884, and the Carondelet Zinc Works have been leased by Mr. Edgar, of the Glendale Zinc Company.

An effort has been made to ascertain the quantity of ore used for the making of the spelter reported. Such an inquiry would shed much light on the conditions affecting the zinc industry in different parts of the country. The returns, however, have been far from being complete. Seven works, East and West, which in the aggregate made 17,127 tons of spelter, report a consumption of ore of 46,870 tons.

Concerning the ore production in southwest Missouri and southwestern Kansas the following data have been collected by good authority. The output of the region was the heaviest in its history, aggregating 74,250 tons, the bulk of which was mined in Jasper and Newton counties, Missouri, and in Cherokee county, Kansas. Of this quantity 67,250 tons was blende and 7,000 tons silicate ore. The zinc works of Carondelet, Rich Hill, and Joplin took 14,550 tons; La Salle, Peru, and Collinsville, 36,500 tons; and Pittsburgh and Weir City, 23,200 tons. Another authority reports the output of the Cherokee county (Kansas) district at 32,987 tons of ore, placing the average price at $15 per ton for the whole of the year 1884. It is stated in a general way, concerning the mines of southwestern Missouri and of southeastern Kansas, that the outlook for an increased production during the current year (1885) is a good one. Promising discoveries of deposits of zinc ore have been made in Central Missouri, along the Kansas City, Springfield and Memphis railroad, and in the northern counties of Arkansas, bordering on the Missouri line.

IMPORTS AND EXPORTS.

Zinc imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Blocks or pigs.		Sheets.		Value of manufactures.	Total value.
	Quantity.	Value.	Quantity.	Value.		
	Pounds.		*Pounds.*			
1867	5, 752, 611	$256, 366	5, 142, 417	$311, 767	$1, 835	$569, 968
1868	9, 327, 968	417, 273	3, 557, 448	203, 883	1, 623	622, 779
1869	13, 211, 575	590, 332	8, 306, 723	478, 646	2, 083	1, 071, 061
1870	9, 221, 121	415, 497	9, 542, 687	509, 860	21, 696	947, 053
1871	11, 159, 040	508, 355	7, 646, 821	409, 243	26, 366	943, 964
1872	11, 802, 247	522, 524	10, 704, 944	593. 885	58, 668	1, 175, 077
1873	6, 339, 897	331, 399	11, 122, 143	715, 706	56, 813	1, 103, 918
1874	3, 593, 570	203, 479	6, 016, 835	424, 504	48, 304	676, 287
1875	2, 034, 252	101, 766	7, 320, 713	444, 539	26, 330	572, 635
1876	947, 322	56, 082	4. 611, 360	298, 308	18, 427	372, 817
1877	1, 266, 894	63, 250	1, 341, 333	81, 815	2, 496	147. 561
1878	1, 270, 184	57, 753	1, 255, 620	69, 381	4, 892	132. 026
1879	1, 419, 791	53, 294	1, 111, 225	53, 050	3, 374	109, 718
1880	8, 092, 620	371, 920	4, 069, 310	210, 230	3, 571	585, 721
1881	2, 859, 216	125, 457	2, 727, 324	129, 158	7, 603	262, 218
1882	18, 408, 391	736, 964	4, 413, 042	207, 032	4, 940	948, 936
1883	17, 067, 211	655, 503	3, 309, 239	141, 823	5, 606	802, 932
1884	5, 869, 738	208, 852	952, 253	36, 120	4, 795	249, 767

Calamine imported and entered for consumption in the United States, 1872 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1872	$193	1882	$622
1873	1	1883	32
1879	10	1884	275

Exports of zinc and zinc ore of domestic production, 1864 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Ore or oxide.		Plates, sheets, pigs, or bars.		Value of manufactures.	Total value.
	Quantity.	Value.	Quantity.	Value.		
	Cwts.		*Pounds.*			
1864	14, 810	$116, 431	95, 738	$12, 269	....	$128, 700
1865	99, 371	114, 149	184, 183	22, 740	....	136, 889
1866	4, 485	25, 091	140, 798	13, 290	....	38, 381
1867	3, 676	32, 041	312, 227	30, 587	....	62, 628
1868	8, 344	74, 706	1, 022, 699	68, 214	....	142, 920
1869	....	65, 411	....	.....	....	65, 411
1870	15, 286	81, 487	110, 157	10, 672	....	92, 159
1871	9, 621	48, 292	76, 380	7, 823	....	56, 115
1872	3, 686	20, 880	62, 919	5, 726	....	26, 606
1873	234	2, 304	73, 953	4, 656	....	6, 960
1874	2, 550	20. 037	43, 566	3, 612	....	23, 649
1875	3, 083	20, 659	38, 090	4, 245	$1, 000	25, 904
1876	10, 178	66, 259	134, 542	11, 651	4, 333	82, 243
1877	6, 428	34, 468	1, 419, 922	115, 122	1, 118	150, 708
1878	16, 050	83, 831	2, 545, 320	216, 580	567	300, 978
1879	10, 660	40, 399	2, 132, 949	170, 654	....	211, 053
1880	13, 024	42, 036	1, 368, 302	119, 264	....	161. 300
1881	11, 390	16, 405	1, 491, 786	132, 805	168	149, 378
1882	10, 904	13, 736	1, 489, 552	124, 638	....	138, 374
1883	3, 045	11, 509	852, 333	70, 981	734	82, 490
1884	4, 780	16, 685	126, 043	9, 576	4, 666	30, 927

PRICES OF ZINC.

The following table summarizes the prices of spelter since 1875:

Prices of common western spelter in New York City, 1875 *to* 1884 *inclusive*.

[Cents per pound. Figures in parentheses are combination prices.]

Years.	January.		February.		March.		April.		May.		June.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1875	6.75	6.37	6.67	6.25	6.50	6.20	(7.00)	6.50	(7.25)	7.15	(7.25)	7.15
1876	(7.60)	7.40	(7.75)	7.50	(7.75)	7.62	(8.00)	7.60	(8.00)	7.75	(8.00)	7.25
1877	6.50	6.25	6.62	6.50	6.50	6.37	6.37	6.25	6.25	6.00	6.12	5.87
1878	5.75	5.50	5.62	5.25	5.62	5.25	5.25	5.00	5.00	4.62	4.62	4.25
1879	4.50	4.25	4.62	4.40	4.62	4.37	4.75	4.25	4.50	4.25	4.37	4.12
1880	6.50	5.87	6.75	6.37	6.75	6.50	6.50	6.12	6.00	5.62	5.50	5.12
1881	5.25	4.87	5.25	5.12	5.00	4.87	5.12	4.75	5.00	4.87	5.00	4.75
1882	6.00	5.75	5.75	5.62	5.62	5.37	5.50	5.25	5.62	5.25	5.37	5.25
1883	4.62	4.50	4.62	4.50	4.75	4.62	4.75	4.60	4.75	4.50	4.62	4.37
1884	4.37	4.20	4.40	4.25	4.60	4.40	4.65	4.50	4.60	4.45	4.60	4.45

Years.	July.		August.		September.		October.		November.		December.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
1875	(7.35)	7.25	(7.25)	7.10	(7.25)	7.10	(7.40)	7.15	(7.40)	7.15	(7.40)	7.15
1876	7.25	7.12	7.25	7.00	7.12	6.80	6.75	6.62	6.62	6.37	6.50	6.37
1877	5.87	5.62	5.90	5.80	5.87	5.75	5.90	5.70	5.87	5.62	5.75	5.50
1878	4.75	4.50	4.87	4.50	4.87	4.75	4.62	4.50	4.75	4.50	4.37	4.25
1879	4.75	4.37	5.62	4.80	6.00	5.62	6.37	6.00	6.25	5.87	6.25	6.00
1880	5.00	4.87	5.25	4.87	5.12	4.75	5.00	4.87	4.90	4.65	4.75	4.65
1881	5.00	4.75	5.12	5.00	5.25	5.00	5.37	5.25	5.87	5.50	6.00	5.87
1882	5.37	5.12	5.50	5.12	5.37	5.12	5.37	5.12	5.12	4.87	4.87	4.50
1883	4.50	4.30	4.40	4.30	4.50	4.40	4.45	4.35	4.40	4.37	4.37	4.35
1884	4.55	4.45	4.62	4.52	4.62	4.50	4.55	4.40	4.40	4.30	4.25	4.00

THE MARKETS IN 1883 AND 1884.

1883.—Values fluctuated within the following range during the year 1883:

Price of spelter in 1883.

[Cents per pound.]

Months.	Highest.	Lowest.	Months.	Highest.	Lowest.
January	4.62	4.50	July	4.50	4.30
February	4.62	4.50	August	4.40	4.30
March	4.75	4.62	September	4.50	4.40
April	4.75	4.50	October	4.45	4.35
May	4.75	4.50	November	4.40	4.37
June	4.62	4.37	December	4.37	4.35

The leading feature of the markets during the first half of 1883 was the heavy falling off in the demand, which caused an early cessation of the importations of foreign spelter, and again gave complete control of the market to home producers. The trade showed a slight recovery during the spring, but subsequently relapsed into great dullness, which continued in July and August, and led finally to the selling off of lots of foreign spelter below the cost of importation, which had been still lingering over the market. Some of the western producers in August showed a disposition to hold off for better figures, but the steady selling on the part of the weaker concerns, and on the part of new works trying to introduce their metal, effectually counteracted this tendency. In September the flooding of some of the Joplin mines, making ores dearer, produced a firmer feeling, and the metal remained steady, but very quiet, during September and the greater part of October. Toward the close of that month there were symptoms of weakness, and there being no improvement in the demand in November, forced sales became more numerous and established a lower level, from which the metal did not recover during the balance of the year, showing, on the contrary, a disposition to fall off further.

1884.—During the year 1884 the monthly range of prices was as follows:

Price of spelter in 1884.

[Cents per pound.]

Months.	Highest.	Lowest.	Months.	Highest.	Lowest.
January	4.37	4.20	July	4.55	4.45
February	4.40	4.25	August	4.62	4.52
March	4.60	4.40	September	4.62	4.50
April	4.65	4.50	October	4.55	4.40
May	4.60	4.45	November	4.40	4.30
June	4.60	4.45	December	4.25	4.00

January and February were dull months, and it was only toward the close of the latter that the first symptoms of an improved feeling appeared. It gained in strength in March, and the trade, galvanizers, and brass manufacturers bought fair quantities, their purchases clearing away the stock and giving values a hardening tendency. A meeting of zinc makers was held in the West to discuss the situation, but they did not reach any definite conclusions as to the best means of harmonious action. Similar meetings in April led to no result, and the market, which had during that month been fairly firm in spite of a small volume of business, began to weaken more and more. A slight recovery took place early in May, but light buying again led to pressure to sell, and June again witnessed lower prices without stimulating the demand. The market dragged along in July, occasional forced sales at concessions revealing clearly how poorly balanced were demand and supply. Under the pressure of such an unsatisfactory state of affairs the spelter makers of the Southwest formed an association, appointed a joint selling agent, and made an allotment of percentages, arranging sales, terms, etc., at weekly meetings. The life of this association, like that of many of its predecessors in the spelter trade, was a short one, owing to causes which it is not necessary to enter into. The association fixed the price at 4⅝ cents; but there were always during its brief career outside lots on the market at lower figures, and some foreign spelter which had been held for a long time was also disposed of. The market remained quiet and dull in August and September, and when in October the association dissolved the majority of its members found themselves with stocks on their hands, and the metal weakened steadily during that month and during November. Early in December offerings from the West were freely made at 4½ cents, followed by sales as low as 4 cents, the demoralization continuing till the close of the year. The metal has since recovered, stocks being absorbed and the demand being on a slightly more liberal scale.

THE PRINCIPAL FOREIGN PRODUCERS.

Total production.—Although our own markets have, during the past two years, been so low that comparatively little spelter has been imported from foreign countries, the conditions affecting the zinc industry abroad deserve close study on the part of American producers. Any sudden improvement in the demand, which the past has taught them may come, will bring them into direct competition with European rivals.

The production of spelter in the world in 1882 and 1883, compiled from the best sources available, was as follows:

The world's production of spelter.

Countries.	1882.	1883.
	Metric tons.	*Metric tons.*
Germany	115, 346	116, 688
Belgium	72, 947	75, 366
France	18, 525	[a] 15, 000
England	[b] 25, 990	[b] 28, 104
Spain	4, 973	4, 233
Austria	4, 791	4, 539
Hungary	605	[a] 600
Poland	[b] 4, 470	[b] 3, 843
United States	30, 628	[c] 33, 459
Total	278, 275	281, 832

[a] Estimated.
[b] Estimated by Henry Merton & Co., London.
[c] Equivalent to 36,872 short tons.

Total consumption.—From the data available concerning the production, the imports, and the exports of a number of countries, the following approximate statement of the consumption of the different countries has been estimated :

The spelter consumption of the leading countries in 1883.

Countries.	Metric tons.
England	79, 000
English exports in brass	9, 000
France	48, 000
Germany	45, 000
Belgium	26, 000
Austria-Hungary	17, 000
Russia	6, 000
India	6, 000
United States	40, 000
Total	276, 000

The balance of the output, say 2,000 metric tons, is the small quantity scattered to other countries. The consumption in Great Britain appears exceptionally heavy. In reality a very large percentage of the amount credited to it is exported as the coating on galvanized iron in many forms which England sends to all quarters of the globe. A good deal of the metal credited to France is in all likelihood shipped out of the country as brass, art castings, etc., for which French shops are famous. The United States in 1883 was a comparatively heavy consumer of spelter, the galvanizing and brass trades being then in a fair condition. As compared with other countries it is certainly still disappointingly small. The low price of copper will, however, probably stimulate the consumption of brass for a variety of purposes and thus prove an aid to the spelter industry of the United States.

Germany.—The production of spelter in Germany is shown by the following table, giving the output of the three great districts, Silesia, the Rhenish provinces, and Westphalia:

Production of spelter in Germany.

Years.	Silesia.	Rhenish provinces.	Westphalia.	Total.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
1878	59, 710	19, 887	15, 631	95, 228
1879	63, 413	18, 942	14, 066	96, 421
1880	65, 798	19, 606	14, 362	99, 766
1881	67, 474	21, 034	16, 764	105, 272
1882	69, 992	24, 654	20, 700	115, 346
1883	71, 468	24, 471	20, 749	116, 688

The total production of ore in Prussia in 1882 and 1883 was as follows:

Production of zinc ore in Prussia.

Years.	Calamine.	Blende.	Total.	Average value per metric ton.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Marks.*
1882	480, 615	212, 754	693, 369	17. 10
1883	457, 979	218, 817	676, 796	13. 09

In Silesia the majority of the zinc works are owned by individuals, whose business results are of course not made public. The largest single concern, however, is a stock company, the Schlesische Actien-Gesellschaft für Bergbau- und Zinkhüttenbetrieb, which in 1883 produced 21,487 metric tons of spelter, of which 18,437 tons was used in the manufacture of 18,383 tons of sheet zinc. In the same year this company made a profit of 1,716,742 marks, and paid 12 per cent. dividends.

In the Rhenish provinces and Westphalia public companies are more numerous, but many of them are producers both of spelter and argentiferous lead. It is not therefore possible to follow closely the effect of varying values of the one metal upon the financial results of the operations. A few data in regard to the latter will, however, be of interest. Thus the Actien-Gesellschaft für Bergbau, Blei- und Hüttenfabrikation zu Stollberg und in Westfalen, produced 14,496 tons of spelter, 13,753 tons of lead, and 23,989 kilograms of silver, realizing a net profit of 452,440 marks, enabling it to pay 4 per cent. on preferred shares. The Rheinisch-Nassauische Berg- und Hütten-Gesellschaft produced 7,672 tons of spelter, 6,512 tons of lead, and 5,953 kilograms of silver; and from sales realized 4,914,441 marks, making a net profit of 155,964 marks, and paying a dividend of 2 per cent. The Bensberg-Gladbach Bergwerks und Hütten Actien-Gesellschaft produced 4,873 metric tons of spelter and 1,530 tons of lead ore, yielding a profit of 202,220 marks, and distributing 6 per cent. dividends. These results are certainly not very encouraging when it is considered that they are only reached by the most vigilant economy and the exercise of the highest mining and metallurgical skill in a country where wages are very low.

The zinc statistics of Silesia are collected in a most thorough manner by the Oberschlesische Berg- und Hüttenmännische Verein, for whose reports for the years 1882 and 1883 we are indebted to Dr. Robert Dahlmann, the secretary. The Silesian mines produced the following quantities of ore during the period from 1878 to 1883, both inclusive:

Output of zinc mines of Silesia, 1878 *to* 1883 *inclusive.*

Years.	Calamine.	Blende.	Total zinc ore.	Average value per metric ton.	Average wages per annum.	Proportion of wages in total value of product.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Marks.*	*Marks.*	*Per cent.*
1878	432,678	57,782	490,460	....	....	....
1879	430,043	62,291	492,334	9.75	373.00	50.37
1880	411,686	81,547	493,233	14.05	398.00	43.67
1881	444,154	99,809	543,963	9.55	400.12	52.30
1882	439,677	120,291	559,968	10.62	398.84	44.54
1883	430,922	122,799	553,721	7.93	403.56	56.60

These figures are particularly interesting as showing that the output of calamine is holding its own fairly well, while the production of blende is quite steadily growing. The value of the ore fluctuates with the price of spelter, while the wages earned by the miners annually vary but little. It is strikingly shown how small the latter are, and it is to be much regretted that figures for comparison are not available for our own country.

On the manufacture of spelter in Silesia the following data are submitted for the period from 1878 to 1883, there being at present twenty-three works in operation:

Statistics of Silesian zinc mines.

Years.	Number of ordinary furnaces.	Number of gas furnaces.	Number of muffles in ordinary furnaces.	Number of muffles in gas furnaces.	Number of muffles used per annum.
1878	216	309	5, 648	11, 220	....
1879	212	315	4, 310	11, 604	153, 377
1880	172	367	4, 180	13, 124	164, 818
1881	162	371	3, 536	12, 808	166, 734
1882	156	354	3, 204	12, 472	162, 548
1883	148	359	3, 092	13, 693	169, 134

It is evident, therefore, that gas furnaces are growing in favor, and that there is a tendency in the direction of their exclusive use. The size of the muffles has been considerably increased.

The following table gives details concerning the consumption of raw materials, number of workmen, wages, and production of the spelter works:

Production of the Silesian spelter works, 1878 *to* 1883 *inclusive.*

Years.	Number of employés.			Average wages per annum.
	Male.	Female.	Total	
				Marks.
1878	3, 862	949	4, 811	....
1879	3, 701	1, 017	4, 718	612. 3
1880	3, 786	982	4, 768	622. 3
1881	4, 042	1, 272	5, 314	598. 1
1882	4, 217	1, 131	5, 348	596. 0
1883	4, 226	1, 285	5, 511	591. 5

Years.	Materials consumed.				Product spelter.	Average value of spelter.
	Calamine.	Blende.	Oxide, powder, dust etc.	Total.		
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Marks.*
1878	425, 875	35, 209	9, 913	470, 997	59, 710	325. 46
1879	439, 755	45, 175	8, 173	493, 103	63, 413	299. 96
1880	485, 499	46, 146	7, 174	538, 819	65, 798	340. 07
1881	454, 881	54, 534	9, 688	519, 103	67, 474	304. 08
1882	449, 078	62, 128	10, 446	521, 652	69, 992	316. 44
1883	444, 849	73, 484	9, 442	527, 775	71, 468	283. 10

On the whole, these figures reveal a steady improvement in the quantity of metal produced and in the amount of labor required to turn out a given amount of spelter. Wages have been lowered somewhat, while the value of the metal has fluctuated within pretty wide limits.

The Silesian zinc mines have always produced some lead ore, in steadily diminishing quantity, and the works turn out some lead annually, the yield in 1883 having been 358 metric tons. At the same time they produce also some cadmium, the amount in 1882 and 1883 having been 3,674 and 2,417 kilograms, valued at 34,537 and 21,536 marks respectively. The consumption of fuel, which was 2.7 pounds of coal per pound of ore in 1860, has been brought down to 1.53 pounds in 1880, 1.37 pounds in 1881, 1.59 pounds in 1882, and 1.74 pounds in 1883. The increase in the last few years is due to the increased quantity of slack and cinder used, the two now by far predominating over dearer sizes It is probable, therefore, that the fuel cost has in reality diminished steadily. In 1882 the zinc works consumed 832,354 tons of coal and in 1883 918,259 metric tons. In 1882 the works used 15,341 tons of refractory clay, and in 1883 12,844 tons, or 0.22 and 0.18 per ton, respectively, during the two years mentioned.

On sheet zinc the report states that four works have eight single and seven double trains of rolls, ten smelting and five heating furnaces, driven by eleven engines, having an aggregate power of 1,160 horse power and water power aggregating 330 horse power. The statistics for the period from 1878 to 1883 are:

Production of sheet zinc in Silesia.

Years.	Number of workmen.	Average yearly wages.	Consumption of spelter.	Sheet zinc produced.	Average value of sheet zinc per ton.
		Marks.	*Metric tons.*	*Metric tons.*	*Marks.*
1878	357	....	19,282	18,824	....
1879	391	541.54	19,805	19,319	346.02
1880	358	546.87	16,686	16,330	378.39
1881	412	621.06	24,509	23,856	360.33
1882	391	624.17	21,230	20,682	344.08
1883	454	652.30	25,623	24,846	328.30

In 1883 the consumption of coal was 25,432 tons, or slightly over 1 ton of fuel per ton of product; though it must be taken into account that two mills, running two double and two single trains, and producing together in thirty weeks 6,321 tons of sheet zinc, were run with water power. The "Silesia" works, running 33.5 weeks, with five single and four double trains, with 1,090 horse-power, produced 15,935 tons of sheet zinc and consumed 23,215 tons of coal.

In 1883 two oxide works, with 15 furnaces and 66 muffles, employing 69 persons, consuming 3,235 tons of spelter and 4,335 tons of coal, produced 3,089 tons of oxide, 174 tons of gray oxide, 23 tons of lead, and 582 tons of residues.

The production of ore in the Rhenish provinces for a number of years is given as follows by the excellent reports of the Verein für die Berg- und Hüttenmännischen Interessen im Aachener Industrie-Bezirk:

Production of zinc ore in the Rhenish provinces.

Years.	Blende.	Calamine.	Total.
	Metric tons.	*Metric tons.*	*Metric tons.*
1878	33,948	15,880	49,828
1879	31,790	21,804	53,594
1880	34,585	19,694	54,279
1881	32,175	16,558	48,733
1882	36,028	18,918	54,946
1883	35,025	16,197	51,222

The proportion of spelter used for the manufacture of sheet zinc is comparatively small in the Rhenish provinces. The following table furnishes a statement of the total quantity of spelter produced and the quantity used for rolling metal:

Production of spelter in the Rhenish provinces and quantity used for rolling.

Years.	Spelter produced.	Spelter used for sheet zinc.	Per cent.
	Metric tons.	*Metric tons.*	*Per cent.*
1878	19, 887	3, 258	16. 5
1879	18, 942	2, 783	14. 2
1880	19, 606	2, 706	13. 8
1881	21, 034	3, 562	16. 9
1882	24, 654	3, 329	13. 5
1883	24, 471	2, 938	12. 0

Combining the direct exports of Germany and the exports from the free port Hamburg the following figures are reached as to the destination of the spelter and sheet zinc produced in Germany:

Exports of spelter from Germany.

Countries.	1882.	1883.
	Metric tons.	*Metric tons.*
Russia	1, 893	1, 737
Austria	9, 258	12, 406
France	7, 174	8, 124
Belgium	1, 564	2, 235
Holland	9, 438	8, 075
Great Britain	21, 591	17, 661
United States	6, 285	3, 345
Other countries	1, 473	758

Exports of sheet zinc from Germany.

Countries.	1882.	1883.
	Metric tons.	*Metric tons.*
Denmark	413	821
Norway	284	453
Sweden	194	268
Austria	285	353
Switzerland	580	456
Belgium	152	....
Holland	3, 438	1, 376
Great Britain	10, 000	9, 926
Italy	46	696
United States	1, 253	386
Other countries	1, 026	1, 535

The total exports of Germany to different countries and to Hamburg were 56,478 tons of spelter in 1882 and 54,939 tons in 1883, and of sheet zinc 14,270 tons in 1882 and 16,505 in 1883. The imports of Holland and to some extent those of Great Britain are of course simply in transit to many different parts of the world. Still, the above tables furnish some clew to arriving at a conclusion as to which the principal consumers of German spelter are, and give an idea to which the two great producing regions, Silesia and the Rhenish provinces, send their metal.

The Russian and Austrian markets are almost exclusively supplied from the former, which also furnishes almost all of the metal shipped in transit via Hamburg, or 19,369 tons of spelter and 6,381 tons of sheet zinc in 1882, and 22,174 tons of spelter and 2,987 tons of sheet zinc in 1883. More than half of the exports to Great Britain, all of those to France and Belgium, and nearly all of those via Holland, are the product of the Rhenish works. The shipments to the United States stood as follows:

Shipments of spelter and sheet zinc from Germany to the United States.

Details.	1882.	1883.
	Metric tons.	*Metric tons.*
Spelter:		
Exported direct	2, 257	2, 524
Via Hamburg	4, 028	821
Sheet zinc:		
Exported direct	209	354
Via Hamburg	899	177

The official statistics of Hamburg specify that in 1882 70 tons and in 1883 88 tons, of spelter, and in 1882 224 tons and in 1883 61 tons of sheet zinc were sent to the Pacific coast of the United States, the balance going to the Atlantic seaboard. How much came to us by way of Holland cannot be ascertained; but the figures given above clearly indicate that the Rhenish metal, notably that of the Stolberg works, finds a market here for a certain quantity less influenced by speculative high prices here than the Silesian spelter, which is first to give way when values decline.

The tables given above clearly illustrate also that the consumers of spelter are the great industrial nations which have a large iron and copper industry; while sheet zinc, a finished product, is far more widely distributed, being taken principally by the building trade.

Great Britain.—As the following table shows, the production of zinc ore has grown steadily for a number of years, the ore mined being almost exclusively blende. The official statistics report the "amount of zinc in the ore," but no effort whatever appears to be made to get officially at the amount of metal produced at the zinc works in the aggregate. As will be noted, Great Britain imports more ore than is obtained from its mines, and the actual output of the metal must be very much larger than that given. From the official statistics the following table has been compiled:

Production of zinc ore in Great Britain.

Years.	Zinc ore (blende).	Zinc in ore.	Years.	Zinc ore (blende).	Zinc in ore.
	Long tons.	*Long tons.*		*Long tons.*	*Long tons.*
1870	13, 563	3, 936	1877	24, 406	6, 833
1871	17, 736	4, 966	1878	25, 438	6, 309
1872	18, 543	5, 191	1879	22, 200	5, 554
1873	15, 969	4, 471	1880	27, 548	7, 162
1874	16, 830	4, 470	1881	35, 527	14, 947
1875	23, 978	6, 713	1882	32, 539	16, 130
1876	23, 613	6, 641	1883	29, 728	13, 603

The only estimate of the quantity of spelter produced in English works which is entitled to acceptance is that made by Messrs. Henry Merton & Co., of London, who have published the following figures:

Production of spelter in England.

Years.	Short tons.	Years.	Short tons.
1880	24,640	1882	28,651
1881	27,349	1883	30,980

How largely Great Britain is dependent upon other countries for its supply of crude and manufactured zinc is clearly apparent from the following table:

Imports of zinc into Great Britain.

Years.	Crude zinc.	Zinc manufactures.	Years.	Crude zinc.	Zinc manufactures.
	Long tons.	*Long tons.*		*Long tons.*	*Long tons.*
1860	24,416		1879	34,180	15,474
1865	32,191		1880	33,409	16,648
1870	31,103		1881	46,198	19,302
1875	37,870		1882	42,001	18,185
1876	29,466	14,719	1883	40,792	20,370
1877	35,094	16,102	1884	47,647	20,138
1878	32,750	16,207			

According to the Board of Trade the imports of zinc ore, crude zinc, and zinc manufactures were as follows:

Details of zinc imports into Great Britain in 1883.

Countries.	Ore.	Crude zinc.	Manufactured zinc.
	Long tons.	*Long tons.*	*Long tons.*
Algeria	15,347		
Belgium	177	13,208	4,277
France	581	846	536
Germany	5	13,234	7,984
Greece	10,105		
Holland	299	13,203	7,534
Italy	16,961		
Australasia	9	266	
United States	694	30	27
Spain	1,642		3
Other countries	15	5	8
Total	45,835	40,792	20,369

The exports of zinc in all forms from Great Britain in 1883, excepting ore, were 7,107 long tons of British zinc and 4,089 long tons of foreign zinc, a total of 11,196 tons, of which 1,444 tons went to Belgium and 6,291 tons to the British East Indies, which, therefore, are the best customers of England. The apparent home consumption of spelter was therefore 86,931 short tons of spelter. It must however be noted that about 10,000 tons per annum of spelter is exported in the brass and yellow metal sent to foreign countries, and a heavy additional amount in the form of galvanized iron, leaving the home consumption roughly at about 70,000 tons of spelter and sheet zinc.

France.—The spelter industry of France is based almost entirely upon imported ores. Out of the 41,000 tons of blende and calamine worked in 1882 only 6,000 tons were produced by mines in France. More than one-half of the 18,525 tons of zinc produced were made at the Auby-lez-Douai (Nord) works of the Compagnie Royale Asturienne, which treats exclusively Spanish ores from its own mines. The Vieille Montagne Company has works at Viviez (Aveyron), and it too relies upon imported raw material. The Compagnie des Zincs Français at Bousquet d'Ore (Hérault) works ore from the Gard department. France is, however, a heavy consumer of spelter. It imported in 1882 34,167 metric tons, exported 4,551 tons, and produced 18,525 tons, thus making its apparent home consumption 48,141 metric tons.

Belgium.—M. Em. Harzé, in his official report, gives the following data concerning the production of the Belgian mines and the output of the Belgian zinc works:

Production of the Belgian mines and zinc works.

Years.	Blende.	Calamine.	Spelter.	Sheet zinc.
	Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*
1870	15, 783	41, 316	45, 754	....
1871	19, 970	41, 159	45, 623	....
1872	20, 623	34, 914	41, 838	....
1873	13, 952	28, 630	42, 314	....
1874	17, 087	26, 212	46, 088	20, 958
1875	18, 750	23, 754	49, 960	23, 476
1876	21, 739	15, 974	47, 981	22, 388
1877	26, 310	18, 677	55, 923	23, 389
1878	27, 134	18, 159	61, 227	23, 178
1879	23, 229	19, 460	57, 157	25, 710
1880	23, 080	15, 735	59, 880	22, 410
1881	8, 169	15, 384	69, 800	25, 394
1882	2, 171	18, 272	72, 947	27, 278
1883	3, 711	16, 924	75, 366	27, 457

The supplies from home mines, it will be noticed, have declined heavily in the face of a constant increase of the production of metal. M. Harzé gives the following details in his report for 1882 and 1883:

Statistics of Belgian zinc works.

Details.	1882.	1883.
Works in operation	11	11
Number of furnaces running	319	327
Number of furnaces idle	48	60
Average number of retorts running	22, 299	22, 521
Number of workmen	2, 864	3, 507
Average daily wages, francs	3. 41	3. 38
Ore consumed:		
Belgian, metric tons	12, 989	19, 250
Foreign, metric tons	161, 632	171, 538
Spelter produced, metric tons	92, 947	75, 366

M. Ch. Hamal, in his report on the mining and metallurgical industries of the province of Liége, in which the entire Belgian zinc industry is centered, states that in 1883 the ores worked in Belgian zinc works were obtained from the following sources:

Sources of ore treated in Belgian zinc works in 1883.

Countries.	Metric tons.	Countries.	Metric tons.
Belgium	19,250	Algeria	1,130
Spain	58,743	Austria	840
Italy and Sardinia	51,227	England	740
Greece	28,903	Other countries	280
Sweden	14,043		
Germany	9,772	Total	190,788
France	5,860		

The production of sheet zinc, as will be noted from the above table, has not during the past ten years kept pace with the increase in the make of the metal, the percentage of the total make rolled dropping from 45.5 per cent. in 1874 to 36.5 per cent. in 1883. In the latter year there were 10 works with 28 trains of rolls, requiring 1,009 horse power, employing 399 hands, to whom average daily wages of 3.62 francs were paid, using 13,084 tons of coal, and employing 29,020 tons of spelter and 279 tons of old and scrap, or 39 per cent. of the raw material produced. The average price realized was 452.48 francs as compared with 363.11 francs per metric ton for spelter.

In 1882 the exports, imports, production, and apparent home consumption of spelter in Belgium were as follows:

Details.	Metric tons.
Production	72,947
Imports	2,314
Exports	49,138
Home consumption	26,123

The largest single producer of zinc in the world is the Vieille Montagne company, whose financial results are, therefore, of special interest. In its fiscal year 1883 the six reduction works of the company turned out 50,015 tons of spelter and produced 44,188 tons of sheet zinc and 5,858 tons of oxide. On this enormous business the gross profit was $644,809, from which general expenses, interest on loans, and applications to sinking and reserve funds, the latter item being $153,854, were paid, leaving a net profit of $343,098.

Spain.—Spain has steadily declined in importance as a source of zinc ore for Belgian, German, and English works, and from all present appearances this tendency will not be checked. The most important mines are in the province of Santander, where the Société Royale Asturienne has the most productive deposit, that of Reocin. The mine is only worked to the extent of the requirements of the two reduction works of the company at Avilès (Spain) and Dunkerque (France), producing about 24,000 tons of calcined calamine at a cost, free on board in port, Spain, of 58 francs per metric ton for ore averaging about 50 per cent. The ores of the Picos de Europa district are more inaccessible but very rich, and constitute the second important group of mines. Other deposits in this and other Spanish provinces are either partially or entirely exhausted or are unfavorably located, so that their yield does not in the aggregate amount to a heavy figure. According to official statistics, which are said, however, to undervalue the product, the output of the Spanish mines has been as follows during the past decade:

Spanish production and exports of zinc ore.

Years.	Production.	Exports of calamine.	Years.	Production.	Exports of calamine.
	Metric tons.	*Metric tons.*		*Metric tons.*	*Metric tons.*
1870	113,583	....	1879	60.980	....
1873	101,009	....	1880	50,521	....
1875	100,174	....	1881	42,911	39,774
1877	70,951	....	1882	....	26,481
1878	74,008	....	1883	....	30,161

The Société Royale Asturienne operates the only zinc works and rolling mills in Spain, located at Arnao, near Avilès, in the province of Asturias, near a small coal field. The output was as follows:

Spanish production and exports of spelter.

Years.	Production.	Exports.
	Metric tons.	*Metric tons.*
1880	4,221	....
1881	4,910	....
1882	5,052	....
1883	4,291	1,401

In 1881 the company produced 2,125 tons of sheet zinc.

Out of the 30,161 tons of calamine exported, 19,615 tons went to France and 9,920 to Belgium. Besides this 15,395 tons of blende were exported, of which Belgium received 14,829 metric tons.

Austria.—From official data kindly furnished by C. von Ernst, the following table of the production of zinc ore and spelter in Austria has been compiled:

Production of zinc ore and spelter in Austria.

Years.	Zinc ore.	Zinc.
	Metric tons.	*Metric tons.*
1879	19,389	3,281
1880	21,564	3,750
1881	23,260	4,119
1882	25,300	4,791
1883	28,749	4,539

In 1883 the Government mined 28.55 per cent. of the total output and produced 34.58 per cent. of the metal. In the same year 2,015 tons of oxide were produced.

The following details of the operations of the Austrian zinc works are compiled from the latest official report:

Operations of the Austrian zinc works in 1883.

Name.	Province.	Production of spelter.	Ores used.	Fuel used. Lignite.	Fuel used. Coal.	Fuel used. Coke.
		Metric tons.	*Metric tons.*	*Metric tons.*	*Metric tons.*	*Metric tons.*
Cilli (government)	Styria	1,570	3,102	11,093	968	962
Sagor (private)	Carinthia	1,137	7,787	....	25,857	....
Siersga and Niedzieliska	Galicia	1,541	12,220	....	40,406	368

The home production of Austria covers only about one-third of its actual requirements.

The exports of spelter from Austria were 972 metric tons in 1883, of which 600 tons went to Germany and 320 tons to Italy. Sheet zinc was exported to the extent of 896 tons, Germany taking the bulk, 747 tons.

The imports of spelter were 12,267 metric tons, which entered free of duty. Germany contributed the bulk of it, 12,195 tons. The imports of sheet zinc were 349 tons, of which 340 tons came from Germany. The apparent home consumption of Austria is therefore 15,834 metric tons of spelter.

Hungary.—The latest statistics available cover the year 1882. In that year 1,511 tons of zinc ore were mined and 605 tons of spelter made, as compared with 798 and 13 tons respectively in 1879.

QUICKSILVER.

Present status of the industry.—The quicksilver industry is in a depressed condition. The production has fallen off largely, but this has not had the effect of stimulating prices to a great extent, though just at the close of 1884 a slight improvement occurred. The leading causes of this depression are the sharp foreign competition in the markets of the world and the decrease in the demand for quicksilver in amalgamating mills. An important outlet for domestic quicksilver, the manufacture of vermilion in China, is apparently closed for the present, the Chinese having obtained their supply in 1884 from other sources. For several years the few California mines in operation have either been worked with a slender margin of profit or at a loss; and one by one the list of producers has dwindled, the survivors being of course the richest and best equipped establishments. The New Almaden was the only one which paid a dividend in 1884. It cannot be said that the outlook for the immediate future is especially cheering. With many metallic products a cheapening in price means an increase in consumption; as, for instance, in the case of copper, which finds a partial relief in the more extended field caused by the growing use of brass in the arts; or as with Bessemer steel, which is gradually supplanting other formerly cheaper materials of construction. The quicksilver consumption, on the contrary, is very inelastic. Important discoveries of gold and silver ores suitable for amalgamation would have a favorable effect on the quicksilver trade, but it is not likely that the amalgamation method will regain its former position in precious-metal metallurgy, as compared with smelting and leaching processes. New utilizations, such as those mentioned in a subsequent paragraph, may, however lighten the market.

Domestic sources.—In addition to the localities enumerated in the previous report a few doubtful occurrences, lacking confirmation, have been reported in the newspapers, but it is safe to say that nothing new of any importance has been found. The actual production is exclusively from the California mines, of which the New Almaden and Guadalupe, in Santa Clara county; the New Idria, in Fresno county; the Sulphur Bank, Redington, and Great Western, in Lake county, and the Napa and Ætna, in Napa county, have furnished nearly all of the recent supply. In the table of production the yield of a number of the less important mines in past years is stated individually. In 1876 about thirty mines were productive, but only eleven yielded any quicksilver in 1884, of which only six produced over 1,000 flasks, and the number was still further reduced at the end of the year. Even the Guadalupe and the Sulphur Bank, mines well equipped with plant for mining and treating ores, have now practically ceased work. The active mines now number but six, with fifteen furnaces in operation. An improvement in the market, if it promised to be lasting, would lead to the reopening of a few of the best of the now idle mines, but for the majority of the abandoned claims there is little hope.

Production.—The statistics of production have been compiled by Mr. J. B. Randol, manager of the New Almaden mine, and present a full report of the American quicksilver output. Mr. Randol's work is a model of statistical completeness. It will be noticed that in 1883 there were 6,007 flasks less made than in 1882; while the decrease in 1884, as compared with the yield in 1883, was even greater, amounting to a difference of 14,812 flasks. The output in 1884 was less than in any year since 1874, and much less than half that of the most prosperous years. It was also below the average for the whole series of years from the inception of quicksilver mining in the United States, the average for the thirty-five years having been 39,695 flasks.

Product of quicksilver mines of California to the close of 1884.

Years.	New Almaden.	New Idria.	Redington.	Sulphur Bank.	Guadalupe.	Great Western.	Pope Valley.	Napa Consolidated.(a)	St. John.	Altoona.	Oceanic.	Oakland.	California.	Great Eastern.	Sunderland.	Cloverdale.	Abbott.	Manhattan.	Various mines.(b)	Total yearly production of California mines.
	Flasks.	*Flasks.*	*Flasks.*	*Flasks.*	*Flasks.*	*Flasks.*	*Flasks.*	*Flasks.*	*Fl'ks.*	*Flasks.*	*Fl'ks.*	*Fl'ks*	*Fl'ks*	*Fl'ks.*	*Fl'ks.*	*Fl'ks.*	*Fl'ks.*	*Flasks.*	*Flasks.*	*Flasks.*
1850	7,723	Production from 1858 to 1866, 17,455 flasks—no yearly details obtainable—included in production of various mines.	......	......	Yearly production previous to 1875 not obtainable (estimated at 20,000 flasks), included in production of various mines.	......	......	......	......	Some was produced prior to 1875, but no record kept (estimated production previous to 1875, 1,000 flasks), included in production of various mines.	......	......	......	......	......	......	......	Yearly production previous to 1876 not obtainable (estimated at 3,594 flasks), included in production of various mines.	......	7,723
1851	27,779		......	......		......	......	......	......		......	......	......	......	......	......	......		......	27,779
1852	15,901		......	......		......	......	......	......		......	......	......	......	......	......	......		4,099	20,000
1853	22,284		......	......		......	......	......	......		......	......	......	......	......	......	......		......	22,284
1854	30,004		......	......		......	......	......	......		......	......	......	......	......	......	......		......	30,004
1855	29,142		......	......		......	......	......	......		......	......	......	......	......	......	......		3,858	33,000
1856	27,138		......	......		......	......	......	......		......	......	......	......	......	......	......		2,862	30,000
1857	28,204		......	......		......	......	......	......		......	......	......	......	......	......	......		..	28,204
1858	25,761		......	......		......	......	......	......		......	......	......	......	......	......	......		5,239	31,000
1859	1,294		......	......		......	......	......	......		......	......	......	......	......	......	......		11,706	13,000
1860	7,061		......	......		......	......	......	......		......	......	......	......	......	......	......		2,939	10,000
1861	34,429		......	......		......	......	......	......		......	......	......	......	......	......	......		571	35,000
1862	39,671		444	......		......	......	......	......		......	......	......	......	......	......	......		1,885	42,000
1863	32,803		852	......		......	......	......	......		......	......	......	......	......	......	......		6,876	40,531
1864	42,489		1,914	......		......	800	......	......		......	......	......	......	......	......	......		2,286	47,489
1865	47,194		3,545	......		......	......	......	......		......	......	......	......	......	......	......		2,261	53,000
1866	35,150	6,525	2,254	......		......	......	......	......		......	......	......	......	......	......	......		2,621	46,550
1867	24,461	11,493	7,862	......		......	......	......	......		......	......	......	......	......	......	......		3,184	47,000
1868	25,628	12,180	8,686	......		......	1,122	......	......		......	......	......	......	......	......	......		112	47,728
1869	16,898	10,315	5,018	......		......	1,580	......	......		......	......	......	......	......	......	......		......	33,811
1870	14,423	9,888	4,546	......		......	1,220	......	......		......	......	......	......	......	......	......		......	30,077
1871	18,568	8,180	2,128	......		......	1,970	......	......		......	......	......	......	......	......	......		840	31,686
1872	18,574	8,171	3,046	......		......	1,830	......	......		......	......	......	......	......	......	......		......	31,621
1873	11,042	7,735	3,294	......		340	1,955	......	......		......	......	......	......	......	......	......		3,276	27,642
1874	9,084	6,911	6,678	573		1,122	1,645	......	1,743		......	......	......	......	......	......	......		......	27,756
1875	13,648	8,432	7,513	5,372	3,342	3,384	1,940	......	1,927	533	......	......	......	412	......	......	......		3,747	50,250
1876	20,549	7,272	9,183	8,367	7,381	4,322	300	573	1,683	1,979	2,358	2,150	965	387	1,570	1,028	1,436	976	2,595	75,074
1877	23,996	6,316	9,399	10,993	6,241	5,856	1,060	2,229	1,463	1,317	2,575	1,395	1,516	505	735	1,291	836	439	1,234	79,396
1878	15,852	5,138	6,686	9,465	9,072	4,963	1,075	3,049	......	1,534	1,679	1,615	1,640	1,366	472	116	......	......	158	63,880
1879	20,514	4,425	4,516	9,249	15,540	6,333	1,325	3,605	1,290	1,919	779	1,505	1,110	1,455	......	18	......	......	101	73,684
1880	23,465	3,209	2,139	10,706	6,670	6,442	275	4,416	492	245	......	166	422	1,279	......	......	......	......	......	59,926
1881	26,060	2,775	2,194	11,152	5,228	6,241	......	5,552	......	......	......	......	......	1,065	......	208	......	......	376	60,851
1882	28,070	1,953	2,171	5,014	1,138	5,179	......	6,842	......	......	......	......	......	2,124	......	......	......	......	241	52,732
1883	29,000	1,606	1,894	2,612	84	3,869	......	5,890	......	......	......	......	......	1,669	......	......	......	......	101	46,725
1884	20,000	1,025	881	890	1,179	3,292	......	4,307	......	......	......	......	......	332	......	......	......	......	7	31,913
Total	813,859	123,549	96,843	74,393	55,875	51,343	18,097	36,463	8,598	7,527	7,391	6,831	5,653	10,594	2,777	2,661	2,272	1,415	63,175	1,389,316

a Including Æcna. *b* The column of "various mines" includes the product of the Buckeye, Mt. Jackson, Bacon, Bella Union, American, Porter, Wall Street, Rattlesnake, Kentuck, and other mines. This column includes, in 1882, 50 flasks produced in Oregon.

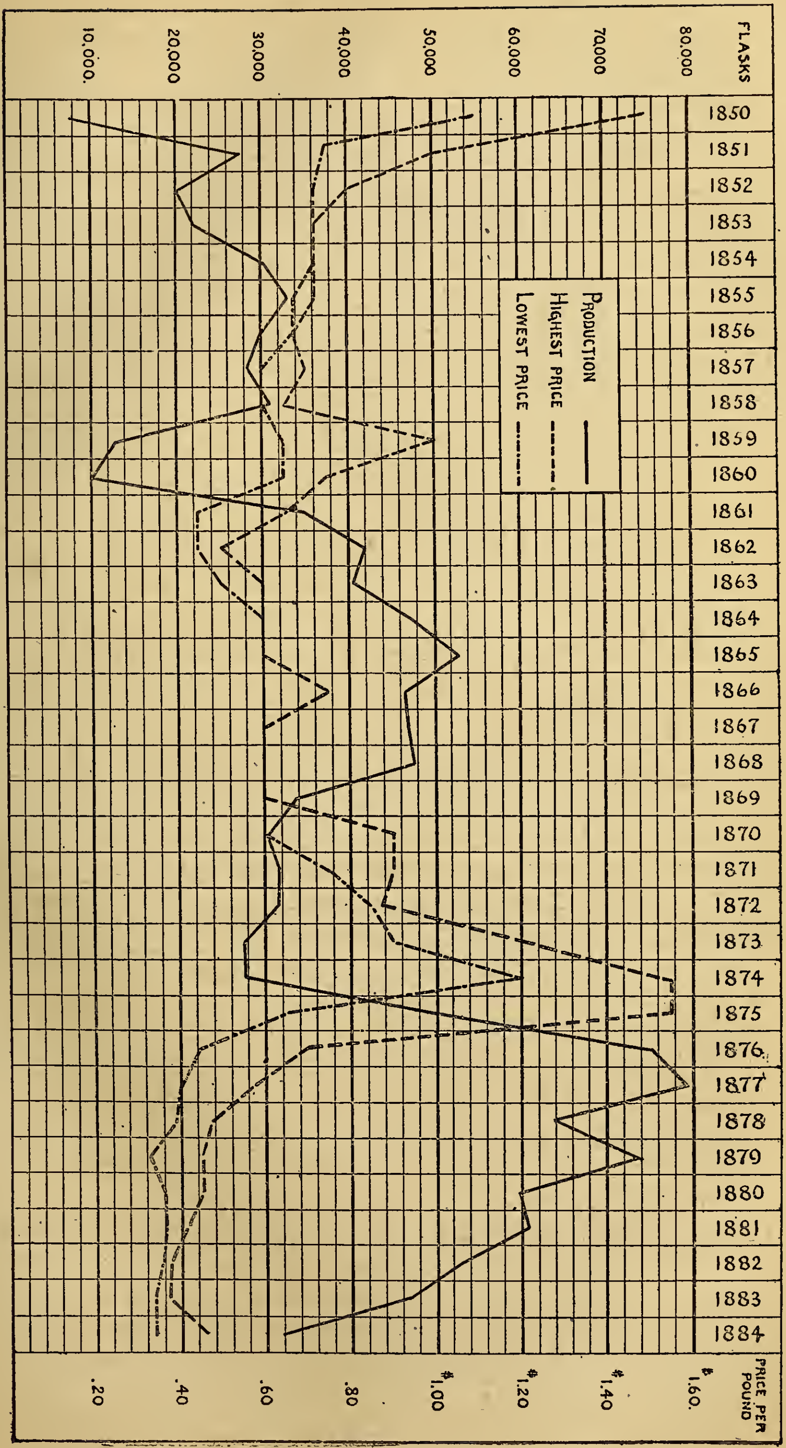

FIG. 6.—PRODUCTION AND PRICE OF QUICKSILVER IN THE UNITED STATES TO DECEMBER 31, 1884.

Production of quicksilver in California in 1883, *by months.*

Months.	New Almaden.	New Idria.	Redington.	Sulphur Bank.	Guadalupe.	Great Western.	Napa. (*a*)	Great Eastern.	Various.	Total.
	Flasks.	*Flasks.*	*Flasks.*	*Flasks.*	*Fl'ks.*	*Flasks.*	*Flasks.*	*Flasks.*	*Fl'ks.*	*Flasks.*
January	2,497	112	367	280	77	390	590	262	7	4,582
February	2,150	133	181	310	7	364	295	156	4	3,600
March	2,230	142	202	335	......	305	485	162	14	3,875
April	1,756	76	243	310	......	294	530	142	3	3,354
May	2,344	144	135	350	......	293	325	164	13	3,768
June	2,214	137	165	91	......	400	360	184	10	3,561
July	2,618	85	141	130	......	446	452	150	2	4,024
August	3,000	139	94	112	......	315	695	76	......	4,431
September	3,010	164	45	265	......	297	750	81	30	4,642
October	2,672	272	109	206	......	215	521	134	......	4,129
November	2,212	115	78	160	......	208	613	102	.....	3,488
December	2,297	87	134	63	......	342	274	56	18	3,271
Total	29,000	1,606	1,894	2,612	84	3,869	5,890	1,669	101	46,725

a Production of Ætna and Napa mines in 1883 under heading of Napa mine.

Production of quicksilver in California in 1884, *by months.*

Months.	New Almaden.	New Idria.	Redington.	Sulphur Bank.	Guadalupe.	Great Western.	Ætna.	Napa.	Great Eastern.	Various.	Total.
	Flasks.	*Flasks.*	*Fl'ks.*	*Fl'ks.*	*Flasks.*	*Flasks.*	*Fl'ks.*	*Fl'ks.*	*Fl'ks.*	*Fl'ks.*	*Flasks.*
January	1,440	103	127	263	....	373	329	135	28	7	2,805
February	1,458	59	104	......	....	241	276	174	9	......	2,321
March	1,606	36	123	68	....	223	249	152	2	......	2,459
April	1,785	75	50	76	....	232	422	69	......	......	2,709
May	1,672	125	53	200	....	169	245	6	......	......	2,470
June	1,859	44	118	......	200	258	215	......	......	......	2,694
July	1,543	29	71	52	200	258	374	101	......	......	2,628
August	1,804	63	47	20	306	334	228	110	......	......	2,912
September	1,448	67	52	35	58	354	136	169	58	......	2,377
October	1,625	115	68	25	160	328	153	90	104	......	2,668
November	1,900	157	32	53	150	230	132	240	91	......	2,985
December	1,860	152	36	98	105	292	172	130	40	......	2,885
Total	20,000	1,025	881	890	1,179	3,292	2,931	1,376	332	7	31,913

Foreign production.—The leading foreign quicksilver mines are the Almaden, in Spain, and the Idria, in Austria. Compared with these, the other foreign sources are insignificant. The Almaden has been worked for hundreds of years, and is still producing largely. Its output from 1564 to 1875 was 120,179 Spanish tons, or 3,482,758 flasks of 75 Spanish pounds (of 76.07 pounds avoirdupois). Up to the close of 1884 it had yielded 3,918,784 flasks, an average production of about 12,000 flasks yearly for 319 years. The Idria mine was discovered in 1490 or 1497, and next to the Almaden has furnished the greater part of the world's quicksilver supply for nearly four centuries. Since 1850, however, the California mines have contributed one-half of the total supply.

Production of the Almaden mine (Spain) and the Idria mine (Austria) from 1850 *to close of* 1884.

Years.	Almaden (in periods of five years).	Idria.	Years.	Almaden (in periods of five years).	Idria.
	Flasks.	*Flasks.*		*Flasks.*	*Flasks.*
1850	101, 517	4, 100	1870	165, 608	10, 745
1851		4, 092	1871		10, 004
1852		4, 085	1872		11, 116
1853		4, 409	1873		10, 939
1854		4, 060	1874		10, 789
1855	110, 058	4, 446	1875	208, 200	10, 717
1856		5, 935	1876		10, 794
1857		9, 189	1877		11, 020
1858		4, 977	1878		10, 403
1859		8, 239	1879		11, 153
1860	122, 117	4, 821	1880	*a*41, 640	12, 356
1861		6, 493	1881	50, 353	11, 333
1862		4, 712	1882	46, 591	11, 663
1863		5, 878	1883	46, 143	13, 152
1864		7, 263	1884	43, 099	*b*13, 000
1865	153, 224	4, 908			
1866		5, 327	Total, thirty-five years	1, 088, 550	288, 982
1867		7, 532			
1868		8, 253			
1869		9, 179			

a Yearly. *b* Estimated.

The world's production of quicksilver from 1850 *to the close of* 1884.

Localities.	Number of flasks.	Pounds avoirdupois to the flask.
California	1, 389, 316	76. 50
Spain	1, 088, 550	76. 07
Austria	288, 982	76. 07
Total	2, 766, 848	
Estimated present yearly production of Italy and other countries	2, 000	

Prices.—Until recently it has been customary in this country to quote the price of quicksilver at so many cents per pound, while in the London market quotations have been in pounds sterling per flask. It is now becoming the rule in San Francisco to state prices by the flask, at the American standard of 76½ net pounds avoirdupois. For convenience in comparing the two systems a conversion table, prepared by Mr. Randol, is appended, which shows equivalent prices per flask and per pound, within the range of recent fluctuations:

Price of quicksilver per flask and per pound.

Per flask.	Equivalent in cents per pound.	Per flask.	Equivalent in cents per pound.	Per flask.	Equivalent in cents per pound.	Per flask.	Equivalent in cents per pound.
$26. 00	33. 98	$29. 00	37. 91	$32. 00	41. 83	$35. 00	45. 75
26. 25	34. 31	29. 25	38. 23	32. 25	42. 16	35. 25	46. 07
26. 50	34. 64	29. 50	38. 56	32. 50	42. 48	35. 50	46. 40
26. 75	34. 96	29. 75	38. 89	32. 75	42. 81	35. 75	46. 73
27. 00	35. 29	30. 00	39. 21	33. 00	43. 14	36. 00	47. 05
27. 25	35. 62	30. 25	39. 54	33. 25	43. 47	36. 25	47. 38
27. 50	35. 95	30. 50	39. 87	33. 50	43. 79	36. 50	47. 71
27. 75	36. 27	30. 75	40. 20	33. 75	44. 12	36. 75	48. 04
28. 00	36. 60	31. 00	40. 52	34. 00	44. 45	37. 00	48. 36
28. 25	36. 93	31. 25	40. 85	34. 25	44. 77	37. 25	48. 69
28. 50	37. 25	31. 50	41. 18	34. 50	45. 10	37. 50	49. 02
28. 75	37. 58	31. 75	41. 50	34. 75	45. 43	37. 75	49. 34

The following table shows the range in price since 1850 in the two great markets. The lowest price ($25.25 per flask) at San Francisco was touched in 1879, though the average for the year 1883 ($26.83 as computed by averaging monthly quotations) was the lowest yearly average. While prices were also very much depressed during the greater part of 1884, a sudden rise to $35 toward the close of the year brought the average of the monthly quotations up to $29.34 for the year. Computed at these averages, the total value of the product of 1883 was $1,253,632, and that of 1884 was $936,327. The highest price was reached in 1874 and 1875, when quicksilver sold up to $118.55 per flask, at which time the demand for amalgamation was great, and before the subsequent temporary expansion in production. Thus the minimum price was less than a quarter of the highest rate obtained, showing a remarkably wide range in values.

Highest and lowest prices of quicksilver during the past thirty-five years.

Years.	Price in San Francisco per flask.		Price in London per flask.					
	Highest.	Lowest.	Highest.			Lowest.		
			£.	s.	d.	£.	s.	d.
1850	$114.75	$84.15	15	0	0	13	2	6
1851	76.50	57.35	13	15	0	12	5	0
1852	61.20	55.45	11	10	0	9	7	6
1853	55.45	55.45	8	15	0	8	2	6
1854	55.45	55.45	7	15	0	7	5	0
1855	55.45	51.65	6	17	6	6	10	0
1856	51.65	51.65	6	10	0	6	10	0
1857	53.55	45.90	6	10	0	6	10	0
1858	49.75	45.90	7	10	0	7	5	0
1859	76.50	49.75	7	5	0	7	0	0
1860	57.35	49.75	7	0	0	7	0	0
1861	49.75	34.45	7	0	0	7	0	0
1862	38.25	34.45	7	0	0	7	0	0
1863	45.90	38.25	7	0	0	7	0	0
1864	45.90	45.90	9	0	0	7	10	0
1865	45.90	45.90	8	0	0	7	17	6
1866	57.35	45.90	8	0	0	6	17	6
1867	45.90	45.90	7	0	0	6	16	0
1868	45.90	45.90	6	17	0	6	16	0
1869	45.90	45.90	6	17	0	6	16	0
1870	68.85	45.90	10	0	0	6	16	0
1871	68.85	57.35	12	0	0	9	0	0
1872	66.95	65.00	13	0	0	10	0	0
1873	91.80	68.85	20	0	0	12	10	0
1874	118.55	91.80	26	0	0	19	0	0
1875	118.55	49.75	24	0	0	9	17	6
1876	53.55	34.45	12	0	0	7	17	6
1877	44.00	30.60	9	10	0	7	2	6
1878	35.95	29.85	7	5	0	6	7	6
1879	34.45	25.25	8	15	0	5	17	6
1880	34.45	27.55	7	15	0	6	7	6
1881	31.75	27.90	7	0	0	6	2	6
1882	29.10	27.35	6	5	0	5	15	0
1883	28.50	26.00	5	17	6	5	5	0
1884	35.00	26.00	6	15	0	5	2	6
Extreme range in thirty-five years	118.55	25.25	26	0	0	5	2	6

Monthly quotations of quicksilver at San Francisco in 1883 and 1884 per flask.

Months.	1883.		1884.	
	Highest.	Lowest.	Highest.	Lowest.
January	$26.75	$26.00	$26.25	$26.00
February	27.25	26.00	29.00	26.00
March	28.00	26.75	29.00	28 00
April	27.00	26.75	29.00	28.00
May	27.00	26.75	29.00	29.00
June	28.50	26.75	29.00	29.00
July	28.50	27.50	29.00	28.75
August	27.50	26.25	30.00	28.75
September	26.75	26.25	31.00	30.00
October	26.50	26.50	30.50	29.00
November	26.50	26.00	34.00	29.00
December	26.25	26.00	35.00	32.00
Extreme range	28.50	26.00	35.00	26.00
Average	$26.83		$29.34	

Imports.—The largest importation of quicksilver was in the fiscal year 1883, when the amount rose to 1,500,000 pounds. In that year, however, the exports were also large, reaching 2,750,000 pounds. The imports during the last fiscal year fell to less than a tenth of the amount imported in the fiscal year 1883.

Quicksilver imported and entered for consumption in the United States, 1867 to 1884 inclusive.

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	......	$15,248	1876	78,902	$50,164
1868	152	68	1877	38,250	19,558
1869	......	11	1878	294,207	135,178
1870	239,223	107,646	1879	519,125	217,770
1871	304,965	137,332	1880	116,700	48,463
1872	370,353	189,943	1881	138,517	57,733
1873	99,898	74,146	1882	597,898	233,057
1874	51,202	52,093	1883	1,552,738	593,367
1875	6,870	20,957	1884	136,615	44,035

Mercurial preparations imported and entered for consumption in the United States, 1867 to 1883 inclusive. (*a*)

Fiscal years ending June 30—	Blue-mass.		Calomel.		Mercurial preparations not otherwise specified.	Total value.
	Quantity.	Value.	Quantity.	Value.		
	Pounds.		*Pounds.*			
1867				$4,242		$2,242
1868				4,440		4,440
1869				4,516		4,516
1870				6,306		6,306
1871				3,147		3,147
1872	1,009	$667	8,241	6,590	$629	7,886
1873	919	660	5,520	5,240	699	6,599
1874	259	192	6,138	6,676	4,334	11,202
1875	125	109	2,424	2,817	52	2,978
1876	489	365	5 433	5,820	92	6,277
1877	455	327	4,649	4,305	90	4,722
1878	397	252	4,133	3,576	363	4,191
1879	485	266	5,875	4,635	6,453	11,354
1880	533	262	4,780	3,330	30	3,622
1881	395	236	8,177	5,640	116	5,992
1882	207	124	5,215	3,411	58	3,593
1883	188	79	8,732	5,503	190	5,772

a Not specified in 1884.

Exports.—The maximum exportation was in the fiscal year 1877, when it reached nearly 4,000,000 pounds. In the fiscal year 1884 less than a third of that amount, and less than half of the amount for 1883, was exported. The yearly exports since 1854 are shown in the following table:

Quicksilver of domestic production exported from the United States.

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1854	....	$94, 335	1870	1, 200, 385	$511, 918
1855	....	806, 119	1871	994, 005	732, 845
1856	....	831, 724	1872	862, 694	691, 637
1857	....	665, 480	1873	714, 783	626, 021
1858	....	129, 184	1874	591, 389	580, 521
1859	....	....	1875	986, 469	1, 075, 796
1860	....	258, 682	1876	2, 711, 584	1, 740, 293
1861	....	631, 450	1877	3, 894, 311	1, 767, 266
1862	....	1, 237, 643	1878	2, 552, 388	1, 230, 608
1863	....	1, 237, 116	1879	3, 624, 827	1, 418, 331
1864	1, 736, 596	976, 868	1880	3, 574, 412	1, 360, 176
1865	....	1, 629, 063	1881	2, 955, 948	1, 124, 955
1866	2, 948, 699	1, 508, 039	1882	2, 485, 551	959, 128
1867	1, 736, 924	750, 673	1883	2, 762, 554	1, 020, 827
1868	2, 995, 789	1, 223, 809	1884	1, 242, 080	427, 219
1869	2, 152, 499	869, 803			

Movement of quicksilver from San Francisco by sea and rail.

Years.	Flasks.	Years.	Flasks.
1850	6, 467	1869	24, 415
1851	10, 791	1870	14, 240
1852	21, 458	1871	16, 339
1853	18, 800	1872	16, 780
1854	20, 963	1873	11, 164
1855	27, 165	1874	11, 750
1856	23, 740	1875	37, 829
1857	27, 262	1876	49, 046
1858	24, 412	1877	52, 695
1859	3, 399	1878	41, 877
1860	9, 488	1879	62, 815
1861	35, 995	1880	46, 294
1862	23, 747	1881	45, 799
1863	26, 014	1882	40, 417
1864	36, 927	1883	37, 867
1865	42, 469	1884	21, 901
1866	30, 287		
1867	28, 853	Tota	994, 001
1868	44, 506		

The shipments shown in this and in the following table do not include supplies sent to local and Nevada precious-metal mines.

Movement of quicksilver from San Francisco in 1883 and 1884 in detail.

To—	1883.	1884.	Increase.	Decrease.
By sea:	*Flasks.*	*Flasks.*	*Flasks.*	*Flasks*
China	16, 330	200	....	16, 130
Japan	1, 253	588	....	665
Mexico	10, 764	5, 404	....	5, 360
South America	970	155	....	815
Australia	600	110	....	490
New Zealand	160	20	....	140
Central America	59	52	....	7
New York	3, 100	8, 350	5, 250	....
Various	11	22	11	....
Total by sea	33, 247	14, 901	....	18, 346
By rail:				
Central Pacific, Southern Pacific, and Northern Pacific railroads	4, 620	*a*7, 000	2, 380	....
Grand total	37, 867	21, 901	....	15, 966

a Including about 3,500 flasks to Mexico by Southern Pacific railroad.

The following table shows the relation of the production to the outward movement, the difference being the balance available for consumption and stock on the Pacific coast:

Relation of production to shipments from San Francisco.

Years.	Production.	Shipments.	Balance.
	Flasks.	*Flasks.*	*Flasks.*
1880	59,926	46,294	13,632
1881	60,851	45,799	15,052
1882	52,732	40,417	12,315
1883	46,725	37,867	8,858
1884	31,913	21,901	10,012

Movement of quicksilver at London.—The imports during 1883 were 54,519 flasks, and the exports 48,997 flasks. In 1884 the imports were 56,969 flasks, and the exports 52,492 flasks. The stock at London December 31, 1884, was estimated at about 74,000 flasks.

Vermilion is an artificial sulphide of quicksilver. In the United States the manufacture centers around New York City, with two establishments in Philadelphia and one in Baltimore. The manufacturers of quicksilver vermilion are: D. F. Tiemann & Co., Sondheim, Alsberg & Co., and A. B. Ansbacher & Co., of New York City; C. T. Raynolds & Co., of New York City and Chicago; G. & N. Poppelin, jr., of Baltimore; J. T. Lewis & Co. and Glahn & Co., of Philadelphia. The production in the past three years is estimated as follows:

Production of quicksilver vermilion in the United States, 1882, 1883, *and* 1884.

Years.	Pounds.	Price per pound.	Total value.
1882	700,000	$0.45	$315,000
1883	650,000	45	292,500
1884	600,000	48	288,000

The falling off in production has been due partly to dullness of trade, and partly to the competition of other reds. The price was for some time stationary at 45 cents per pound, until November 22, 1884, when it was advanced to 55 cents, on account of the rise in price of quicksilver.

The genuine quicksilver vermilion is known as "quicksilver," "California," or "English" vermilion. It is claimed to be of better quality than the imported, though the latter sells at 10 to 15 cents higher per pound. While there is probably little intrinsic difference, the home manufacturers are in better position to understand the taste of local consumers. The domestic vermilion is made from California quicksilver or from the foreign metal, indifferently, but more commonly from the former. The process is reported by Mr. Marcus Benjamin to consist in bringing quicksilver, sulphur, potassium hydroxide, and water together in a revolving drum. The mixture is gently heated until 115° Fahr.

is reached; the temperature is then kept constant, and the reddening action proceeds. The composition of the vermilion is approximately mercury, 86.3 parts; sulphur, 13.7 parts.

A number of pigments known as vermilion, but not made from quicksilver, are on the market, under the names of "American vermilion," a chromate of lead, also known as "Persian red," "Persian scarlet," "chrome red," "scarlet vermilion," etc. About 1,000,000 pounds of this material were made in 1883, and 750,000 pounds in 1884. "Imitation vermilion" is an aniline color thrown on a lead body (oxide or carbonate), and is said to be fugitive. There are numberless names for it; "Columbian red," "zubia," "ruboide," "Roman red," "Swiss red," etc. These colors have largely superseded true vermilion, as they are of a brilliant red, stand exposure fairly well, changing to a lighter color instead of a darker, as is the case with genuine vermilion, and are very much lower in price. The production of aniline vermilions was about 750,000 pounds in 1883, and 600,000 pounds in 1884. The chromate of lead vermilions sold at about 11½ cents per pound in 1883, and following the gradual decline in white lead (carbonate) fell to 10½ cents in 1884. The various grades of aniline vermilion brought from 10 to 35 cents per pound in 1883, and declined to 8½ to 25 cents in 1884, owing to the removal of the duty on aniline and eosine. Quicksilver vermilion is considered to be superior in body, permanency, and richness, but the question of price affects the sale. The scarlet chromates of lead, while possessing enduring qualities, lack body and are not so rich in color. Between the two, of late years, the eosine reds have appeared. Their color is exceedingly brilliant, and the body good; but their comparatively fugitive character is a drawback.

In 1883 there were 16,330 flasks of quicksilver sent from the United States to China, all of which is supposed to have been made into vermilion in the latter country; but in 1884 the Chinese market was supplied with Spanish quicksilver sent from London, though a little American quicksilver may have reached China indirectly and thus escaped record.

The imports of vermilion, with their declared foreign valuations, have been as follows:

Vermilion imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	....	$123,506	1876	18,98[illegible]	$17,680
1868	....	90,648	1877	23,315	14,660
1869	247,382	145,665	1878	9,843	5,772
1870	104,523	57,262	1879	11,382	6,105
1871	79,195	43,935	1880	11,952	5,997
1872	120,067	49,237	1881	14,243	7,392
1873	87,008	65,796	1882	12,496	6,215
1874	42,324	39,443	1883	19,549	8,796
1875	9,460	10,831	1884	(*a*)	10,473

a Not specified.

New uses for quicksilver.—Mr. J. A. Bauer has called attention to the use of quicksilver as a preventive and cure for phylloxera. Corrosive sublimate was first tried by Mr. Bauer, but was not found to answer, as the mercuric chloride was speedily decomposed by the earths of the soils to which it was applied. The quicksilver is used in mixture with fine powdered clay, equal weights of each, and is so finely divided that separate globules of the metal cannot be distinguished under an ordinary microscope. This mixture of quicksilver and clay is added to the soil of the hole in which the vine is planted. Half an ounce of quicksilver to each vine is said to be about the proper quantity. The clay used must be free from grittiness; the mixture with the quicksilver is done in revolving barrels. A number of experiments, said to have resulted satisfactorily, have been made. Another use has been suggested, namely, the use of a weak solution of corrosive sublimate (bichloride of mercury) as a disinfectant and germicide in case of epidemic cholera. These applications, if adopted on a large scale, would do much to relieve the quicksilver market.

QUICKSILVER REDUCTION AT NEW ALMADEN.[a]

By Samuel B. Christy.

The mines of New Almaden were opened some years previous to 1850. The regular workings of which records have been kept extend from that date to the present time. During the thirty-four years ending with 1883, the quicksilver product of these mines has been exceeded by that of Almaden in Spain only. During this period, the yield of New Almaden has been 79 per cent. of that of its namesake in Spain, three times that of Idria in Austria, and greater than that of all the other mines in the world put together. Very little, however (almost nothing, in fact), has ever been published regarding either the mine or its works. These facts, together with the energy with which improvements have been introduced and perfected at New Almaden, particularly during the last ten or twelve years, justify the length and detailed nature of the present paper.

This study of quicksilver reduction will consider:

1. The ores: their sorting and classification.
2. Methods of reduction: historical sketch.
3. Reduction works: their situation and arrangement.
4. Furnaces: their construction, mode of operation, and economic results.
   a. Intermittent furnaces.
   b. Continuous coarse-ore furnaces.
   c. Continuous medium-ore (*granzita*) furnaces.
   d. Continuous fine-ore (*tierra*) furnaces.

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[a] A paper read before the American Institute of Mining Engineers.

ORES.

Sorting and classification.—As is well known, the ore at New Almaden is cinnabar. Native quicksilver occurs also; but, as a rule, in small quantities only. Pyrite occasionally accompanies the ore. Bitumen is quite common, sometimes as a fragile black lustrous solid, resembling soft bituminous coal, but melting easily like tar; at other times it occurs in the vugs of the gangue, in a liquid state, like coal tar. I have found lumps of apparently pure cinnabar from New Almaden to give a voluminous residue of pulverulent charcoal when subjected to sublimation out of contact with the air. This would seem to show that the bituminous substance is intimately associated with the cinnabar. The latter occurs associated with a gangue of serpentine, dolomite, and a hard chalcedonic or soft chloritic "vein matter." Very rarely the ore is found disseminated in sandstone.

The "vein matter," just as it is broken in the *labores*, or stopes, of the mine, is run out in ore cars on an elevated tramway above the *planilla*, or dressing floor, belonging to each center of production. At the Randol *planilla*, for instance, this tramway is 14 feet 6 inches above the dressing floor.

Beneath these tramways, at convenient intervals, are placed bar-screens inclined at 45°. The bars, slightly chamfered at the bottom to prevent choking, are placed an inch to an inch and a quarter apart. To prevent spreading they are stayed with iron cross-bars at intervals of 4 feet. Their total outside width is 5 feet. Upon these screens the ore is dumped, and what passes through is known as *tierras*. The coarse fragments which fail to pass the screens are carefully examined, and any lumps that show signs of cinnabar are broken by hand to a maximum diameter of 9 inches, and the waste is rejected. The picked ore is known as *granza*.

During 1882 and 1883 the totals from the mine were as follows:

Sizes.	Tons of 2,000 pounds.	
	1882.	1883.
Coarse material:		
Waste rock from vein, rejected	45,097.08	44,147.20
Coarse ore (granza)	9,236.43	9,584.20
Screenings, fine ores (tierras)	14,705.81	20,289.24
Total product from ore chambers	69,039.32	74,020.64

This table shows that about one-sixth only of the coarse material stoped is sent to the works for treatment. All the fine ore is sent there.

Besides these ores which come from the present workings, there is another supply, coming from the old dumps, mostly situated at the mouth of the main tunnel. These dumps are now being worked for a second time. In handling this material, all large lumps that are evidently waste are immediately rejected; the rest is dumped upon screens similar to those just described. The screenings furnish "old dump *tierras*." The coarse fragments are broken and washed in a large tank on ore forks, to remove the dust with which they are covered; and any fragments which show even a color of cinnabar are set aside as *terrero*. This has a maximum diameter of 6 inches.

The product of the old dumps for 1882 and 1883 was as follows:

Sizes.	Tons of 2,000 pounds.	
	1882.	1883.
Terrero	322	261.27
Tierras	9,522	10,953.05
Total yield	9,844	11,214.32

The old dumps, being exposed to the weather, are worked only during the dry season, while at the regular mine planillas, which are covered by sheds, the work goes on all the year round.

The cleaned ores are transported to the ore chutes and bins at the *hacienda* (the name given to the reduction works). Here they are still further classified, partly by the screens in the ore chutes, partly by screens on the top of the ore cars. By this means, a new class of ore is introduced, intermediate in size between the *tierras* and the *granza*. This class is called *granzita*. The screens at the ore chutes are mostly made of cast-iron plates, with 1¼-inch square holes arranged in diagonal rows across the plate. These separate from the mine *tierras* and *granza* a certain quantity of coarser fragments (*granzita*) that has passed the bar screens at the planilla, owing to the shape of the fragments or to the spreading of the bars.

The same ore product is, therefore, classified somewhat differently at the mine and at the works. Thus:

At mine:
  New mine, old dump: Granza, coarse (rich); Tierras, fine (poor); Terrero, coarse (poor).
At works:
  Granza, 9 in.–3½ in. (rich); Terrero, 6 in.–3½ in. (poor); Granzita, 3½ in.–1¼ in. (poor); Tierras, 1¼ in.-dust (poor).

It will be observed that at the works no distinction is made between new mine and old dump *granzita* and *tierra* ores.

The general effect of a heap of *granza* ore with a light green background of serpentine and "vein matter," lighted up by bright masses of cinnabar, is quite pleasing to the eye. This class of ore usually runs at present from 6 to 8 per cent. metallic quicksilver.

The *terrero* has much the same composition as the *granza;* only its exposure to the weather on the dump has given it a dull rusty look, and its quicksilver content is not more than 1 to 2 per cent.

The *tierras* and *granzitas* vary, according as they come from one or the other of the above classes of ore, from a dull green to a rusty, earthy appearance. Fragments of cinnabar are easily detected by the eye in some cases, and in others only by panning. Their quicksilver content usually averages 1 to 3 per cent.

The total product of the mine for 1882 and 1883, classified as above explained, was:

Sizes.	Tons of 2,000 pounds.	
	1882.	1883.
Granza	9,236.43	9,584.20
Terrero	322.00	261.27
Tierras	24,657.81	31,242.29
Totals	34,216.24	41,087.76

The total amounts treated at the reduction works for the same periods were:

Sizes.	Tons of 2,000 pounds.	
	1882.	1883.
Granza	9,569.85	10,428.40
Terrero	297.60	185.35
Tierras and granzita	26,206.15	27,967.50
Totals	36,073.60	38,581.25
Average percentage of quicksilver	2.976	2.875

The difference between these sums total and the product of the mine is, of course, accounted for by the ore left over in the ore bins.

The ore on hand at the reduction works for the end of these periods was:

Sizes.	Tons of 2,000 pounds.	
	Dec. 31, 1882.	Dec. 31, 1883.
Granza	1,265.990	421.790
Terrero	195.375	271.295
Tierras and granzita	2,330.378	5,605.162
Totals	3,791.743	6,298.247

The *granza* and the *tierras* are weighed on platform scales as they leave the planilla; the *terrero* and *tierras* from the old dump are estimated by volume. At the works, the *granza* only is weighed; the *granza* screenings, *granzita*, and *tierras* are estimated by volume. The latter, by experiment, weigh about 85 pounds per cubic foot, or 23.5 cubic feet per ton.

It is evident that more than two-thirds of the total product of the mine is in the form of smalls. The method of treatment must, therefore, be adapted to this fact.

METHOD OF REDUCTION.

Historical sketch.—The above account of the nature of the ores in mind, the following sketch of the gradual development of the methods now in use will be more intelligible. (*a*)

The first attempt at quicksilver reduction was made by treating the ores in whalers' trying vats. These were made into retorts by luting on iron covers; but so much salivation of the men resulted from their use that they were soon abandoned, and regular iron retorts were introduced instead. The retort process necessitated crushing all the ores in order to mix them with lime, and was so expensive that only the rich ores would pay for treatment. As a consequence, concentration by washing or a total rejection of the poorer ores was necessary, in either case giving rise to considerable loss. Hence, even before 1850, attempts were made to treat all the ores, as was then done at Idria, Austria, and at Almaden in Spain, by roasting them and condensing the quicksilver from the products of combustion.

The first furnaces built were badly constructed, with poor materials, and gave rise to the loss of much metal in the foundations. But experience soon led to the type of intermittent furnace afterwards widely used in California. One of these furnaces, known as No. 6, is still in use at New Almaden, and with the other furnaces now used will be described in detail later on.

This furnace was a great improvement on the old retort system. It was also an improvement on the intermittent furnaces then in use at Idria and Almaden; for the ore was supported by a solid floor and not by arches attacked from below by the full force of the flames. It had, however, all the disadvantages common to discontinuous furnaces. In the treatment of quicksilver ores, the dislocation of furnace and condenser walls, resulting from sudden changes of temperature, was particularly injurious. The quicksilver escaping, both as liquid and as vapor, from these openings caused both loss of metal and injury to the men. But the most serious disadvantage was the difficulty of treating the fine ores in these furnaces. The *tierras*, forming, as we have seen, the greater part of the product of the mine, had to be mixed with clay

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a Most of the standard works on metallurgy state that quicksilver is reduced at New Almaden in retorts. This was once true; but, as nearly as can be now learned, has been abandoned since 1850. Retorts were used at the Enriquita works later, till 1858 or 1860, for ore reduction; at New Almaden proper (the *hacienda*) they were used after 1850 only for making assays or tests with rich ores. Since 1860, they have been entirely abandoned.

and made into sun-dried bricks, locally called *adobes* (*a*), before they could be roasted at all in the furnaces then used. As the *tierras* from which the adobes were made were poor ores, the expense of making them largely reduced the profit of treating these ores.

The next important improvement was the introduction of the continuous coarse-ore furnace. This furnace was first invented and built for burning lime near Berlin by the celebrated Count Rumford.(*b*) It was first introduced at Idria, Austria, by Bergrath Adolf Exeli in 1871, and proved so effective there that its introduction at New Almaden followed in 1874. The first furnace worked so well that a second was built in 1875. These furnaces, locally known as Nos. 7 and 9, are also called "monitors," in allusion to their shape, and to the fact that they are iron-clad. With the introduction of these furnaces, the economical treatment of the coarse ore was satisfactorily accomplished.

But the most serious problem yet remained. Two-thirds of all the ore had still to be worked into *adobes*, whether it went through the monitors or the intermittent furnaces. The fine ores of Almaden in Spain are even yet made into *adobes*, while at Idria, Austria, this class of ores is treated in continuous reverberatory furnaces (*Fortschaufelungsöfen*). At New Almaden, the problem has been solved in a much happier manner by the invention of the Hüttner & Scott furnace. This must be regarded as the most important contribution to the art of quicksilver reduction that has originated at New Almaden. The general idea of this furnace is similar to that of the Hasenclever-Helbig shelf furnace. In common with the latter, it utilizes a series of inclined shelves, placed in the opposite walls of a narrow vertical shaft to retard the descent of a column of fine ore. But it differs from the Hasenclever type in combining a number of ore chambers in the same structure, and in the devices for regulating the passage of the products of combustion and for effecting the discharge.

The original experimental furnace, No. 5, contained two high, long, and narrow ore chambers, separated by pigeon-hole walls from the fireplace on one side and the vapor chamber on the other. From either wall of the ore chambers projected tile shelves, placed alternately in the opposite walls. These shelves were inclined at an angle of 45° to the walls, and each shelf was therefore perpendicular to the next lower one in the opposite wall. The distance from the edge of one shelf to the face of the next below it was 3 inches, thus forming an aperture

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a The adobes were made in wooden frames by hand, just as bricks are made, the frames forming six at a time. The molds were 4¼ inches by 5¼ inches by 10¼ inches inside measure; and the sun-dried adobe weighed about 12 pounds. In 1875 the cost of making the adobes was 50 cents per ton, and that of handling them afterwards, drying, etc., 45 cents per ton. Total additional cost of treating *tierras*, 95 cents per ton.

b Described in Karsten's *Archiv für Mineralogie, Geognosie, Bergbau und Hüttenkunde*, 1837, pp. 645–702.

through which the ore could pass. This aperture I shall call, for convenience, the "shelf slit."

When fine ore was fed into this ore chamber through a hopper at the top, it ran from one shelf to the next, until the column found support upon the discharge apparatus at the bottom, whereupon the whole column came to rest throughout the structure. Thus the shelves of the ore chambers were kept covered by an irregular zigzag column of ore. The end walls of the chamber were pierced with pigeon holes, so that the flames might pass from the fireplace under each shelf, and over the ore lying upon the shelf beneath to a vapor chamber on the opposite end of the ore chamber. Thence they passed to the condensers. In the first experimental form, the flames made only one passage across the ore chambers. The furnace, as thus constructed, roasted the ores well enough; but the escaping vapors were still quite hot, and the consumption of fuel was considerable.

To render the furnace more economical of fuel, to confine the greatest heat to the bottom of the furnace, so as to secure the thorough roasting of the ore, and to allow the vapors to escape to the condensers just above the boiling point of quicksilver, was the next object. All the above improvements in the working of the furnace were effected by placing arches across the vapor chambers and over the fire box, so that the air and fumes were compelled to make four passages across the furnace on their way to the condensers. First, the air which entered the fireplace was drawn through the roasted ore, thus absorbing its heat, and removing any quicksilver vapor which it might contain. Next, the hot products of combustion passed through the nearly roasted ore, thus imparting to it a maximum temperature; and finally they were passed again back and forth through the colder ore in the upper half of the ore chamber. In this way the excess of heat was imparted to the cold ore, and the fumes left the furnace for the condensers only moderately heated above the boiling point of quicksilver. With these changes the furnace was found to do uniformly good work at a small expenditure of fuel and labor.

The capacity of No. 5 was at first only 6 tons per twenty-four hours. It was afterwards increased to 12 tons, but it was evident that the full economy of the new furnace could only be attained when it was erected on a larger scale. Consequently in the same year, 1876, a larger furnace, No. 8, was erected. This was a double furnace, two furnaces similar to No. 5, but larger, being united end to end in the same structure. It was originally supposed that one of these might be repaired while the other was in use. Experience has shown the heat to be too great to allow this; and they are now always used together without inconvenience.

In 1877 and 1878 a new furnace, No. 3(*a*), was started. While this fur-

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[a] Most of the furnaces at New Almaden are built on the sites of old intermittent furnaces, and retain their numbers as a survival. To avoid confusion, the designations used at the works are retained in this paper.

nace was of the same type as its predecessors, its capacity was still greater, and it differed in having three pairs of ore chambers placed side by side, and all heated by the same fireplace. Another modification was introduced in the middle pair of ore chambers. These were made with a 5-inch shelf slit, and were to be used for roasting *granzita;* but it was found that the temperature best adapted for roasting *tierras* was not suited for *granzita*, and *tierras* only are now treated in all the chambers of this furnace.

Finally, in 1879, a new furnace, No. 2, with two ore chambers, having an 8-inch shelf slit, was introduced for treating the *granzita* ores, intermediate between *granza* and *tierras*. The *granzita*, it will be remembered, runs from 3½-inch down to 1¼-inch diameter. In 1880, a second *granzita* furnace, No. 1, was built with two pairs of ore chambers. With the above improved furnace plant, the economical treatment of fine and medium quicksilver ores may be said to be accomplished.

In the early history of the mine, according to most accounts, the condensation of quicksilver was very imperfectly effected. Prof. W. P. Blake, in a letter to Prof. J. D. Dana (*a*), dated February 14, 1853, speaks of the loss of mercurial fumes escaping from the chimneys, and of "the peculiar gray coating upon their tops." An article in the American Cyclopedia, some ten years later, speaks of the salivation of men and animals about the works, and "the deposit of mercurial soot upon the roofs around." During the last ten or twelve years, while improvements have been going on in furnace construction, constant attention has been given to the subject of condensation.

REDUCTION WORKS.

Situation and arrangement.—The beautiful spot occupied by the *hacienda*, or reduction works, is familiar to many California travelers. It was chosen in the early history of New Almaden. The road leading to the mine leaves the San José valley, and, turning to the south, enters the cañon of Los Alamitos creek. The handsome residence of the manager and the neat village of the officers and the workmen make a pleasing picture to the east of the well-shaded road. This latter is cooled by a running stream, a luxury all too rare in California summers. Just above the village the narrow cañon widens out to an area of a dozen acres, giving barely room for the reduction works. The summit of Mine hill is a mile to the west of the *hacienda* in a direct line, and 1,300 feet above it. A fine wagon road, 3 miles in length, and a shorter tramway, with self-acting inclines, serve to bring the ore from the mine to the works.

The ore tramway from the mine is situated at the foot of the tall bluffs behind the furnace, at a height of 60 feet above the furnace floor. From thence the ore is dumped into the ten chutes arranged

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a American Journal of Science, Vol. XVII., p. 438.

along the sloping sides of the bluff at an angle of 40°. These are arranged with bar or cast iron screens, as before described, to separate the *tierras* from the *granzita*, and have in most cases aprons of hanging logs to retard the descent of ore and facilitate the removal of smalls.

The *granza* and *terrero* go directly from the chutes to the furnaces; but as there is not storage capacity enough in the chutes for the *tierras* and *granzitas*, the latter are distributed by elevated tramways to the ore sheds, arranged at convenient points in the furnace yard. It is necessary to accumulate during the summer months a stock of these ores to last through the winter, as they would be too wet to roast if exposed to the rains. This is all the more necessary since they already contain considerable moisture, and must usually be dried before roasting.

Near the furnaces are the bottling and weighing rooms. These are kept under lock and key, and are in the charge of the watchmen. The quicksilver is conducted from the entire system of condensers belonging to each furnace by iron pipes which lead to boxes, with goose-necks at the bottom, from which nearly constant slender streams of quicksilver flow during the regular working of the furnaces. The metal is allowed to accumulate in large iron vats, whence it is weighed out into flasks, bottled, and stowed ready for shipment. The product of each furnace is recorded separately.

After passing through the condensing system attached to the furnace in which it is produced, the smoke is conducted to brick towers. In these brick towers auxiliary fireplaces are placed to heat the side-hill flues in case of insufficient draft. The side-hill flues lead to tall brick chimneys on either side of the creek, which serve to dissipate the products of combustion.

The spent ore, or waste, locally termed "slag," is drawn from the cooling pits of each furnace into cars, whence by tracks it is dumped into Alamitos creek, which effectually disposes of it.

Owing to the lack of sufficient level space for stowing ore above the furnace heads, three elevators are used to lift the *tierras* and *granzitas* from the floor of the works where they have been stored (or dried in the sun during the summer) to the top of the furnaces. Two of these are water-balance elevators, while the other is a water-pressure elevator with piston.

The furnaces, condensers, and ore floors are roofed over; but the sides of the structures are mostly left open to afford free ventilation for cooling the condensers and drying the ores.

Despite the necessity of making all improvements without any interruption to the regular production, the works are well and conveniently arranged, and are kept in excellent order.

In addition to the main plant above mentioned, there are soot floors and kettles, bath rooms for the men, offices of the company, carpenter shop, and machine shop. The latter is furnished with between 3 and 4 horse power by an overshot wheel, 6 feet wide and 20 feet in diameter,

FURNACES. (a)

After this general view of the works a detailed study of the furnaces themselves comes next in order. No further mention will be made of devices now abandoned, and we shall consider only those furnaces now in actual use.

INTERMITTENT FURNACES.

Furnace No. 6.—This is the last survival of the old intermittent furnace in its most perfect form. The ore chamber, which forms the main body of the furnace, is separated from the fireplace and the vapor chamber by pigeon-hole walls. These walls have in plan the form of an arch with the convexity towards the ore chamber, as they serve to keep the ore from the vapor and fire chambers. The ore is charged into the ore chamber through the top of the furnace, being lowered in a Mexican ore basket by hand. A series of "channels" or flues is built along the bottom across the ore chamber, in continuation of the apertures in the pigeon-hole wall, with lumps of coarse ore. In former times adobes were used for this purpose. When the first series of channels has been built, a layer of coarse ore 2 or 3 feet thick, according to the size of the fragments, is charged into the furnace; then another series of channels is built, and so on to the top of the furnace. To counteract the natural tendency of hot air to roast the upper rather than the lower layers of ore, the channels are made smaller and farther apart in the upper layers of ore, and a certain amount of *tierras* and soot from the condensers is added to the coarse ore for the same reason. The ore-chamber is 12 feet long by 9 feet wide, and 17 feet 6 inches high, inside measures; and the charge of ore is 80 to 100 tons. The discharge ports or draw holes are four in number, two on each side of the furnace. They are bricked up during the roasting of a charge, except a peep hole, kept tight by a luted brick. The final discharge opening for the fumes has its bottom on a level with that of the ore chamber, and its top at a height of 6 feet 9 inches above the floor. This is to counteract the upward tendency of the gases, already mentioned.

The operation of these furnaces as now managed (without adobes) is as follows:

1. *Charging.*—This takes the labor of eight men for one day. As already described, the coarse ores (*granza* and *terrero*) are used to build channels, the coarse ores are next piled in indiscriminately, then another series of channels, and so on, till a layer of soot and *tierras* fills the furnace to the top. The draw ports are then bricked up; on top of the charge pieces of old sheet iron are laid; on these is placed a 2 or 3 inch layer of straw manure, and on the latter a layer of moist clay of about the same thickness. The furnace is then ready for the second period.

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a The unavoidable omission of the large and detailed furnace drawings which accompanied the original paper is regretted, as these would have greatly assisted the description.—A. W., jr.

2. *Roasting.*—This requires in most cases the labor of one man per shift of twelve hours for five days and four nights. Besides attending to the firing, the man in charge of the furnace lutes any cracks that may appear in the port-hole doors, and from time to time sifts ashes over any cracks that may form in the clay luting that covers the top of the furnace.

3. *Cooling.*—This, of course, requires no labor. When the firing is stopped, the furnace is allowed to cool for three days and nights, the air passing through it into the condensers all the time, removing any quicksilver that may be still retained in it, and cooling the ore so that it may be handled by the men.

4. *Discharging.*—For this the labor of four men for one day is necessary. The top is removed to create an upward draft through the furnace; the discharge ports are broken open; and the men draw the spent ore through the ports into the slag cars.

In this manner a charge of ore is finished in just ten days; so that three such charges may be put through in one month. Formerly, when the intermittent furnaces only were used, less time was given to the roasting and cooling periods in order to increase the production. As a consequence, the ore was not always thoroughly roasted, and the men who charged and discharged these furnaces suffered considerably from the heat and the fumes of the mercury. The time of roasting and cooling such a furnace should of course be greater with rich than with poor ores; and the fact brought out by the present management that sufficient time was not allowed to properly roast rich ores in these furnaces explains in large part the losses and evils formerly connected with their use.

No. 6.—*Coarse-ore furnace* (*intermittent*).

Number of runs.	1882.	Number of days' firing.	Granza, tons.	Terrero, tons.	Tierras, tons.	Total ore, tons.
One run	Jan	4½	39.60	21.60	21.90	83.10
Two runs	Feb	8½	125.30	2.70	44.00	172.00
Two runs	Mar	11	149.60	1.80	31.50	182.90
Two runs	April	9⅙	160.60	....	16.50	177.10
Three runs	May	13½	201.30	36.00	25.50	262.80
Three runs	June	13½	191.40	64.80	12.00	268.20
Three runs	July	12½	240.90	23.40	6.75	271.05
Three runs	Aug	12½	168.30	83.70	6.75	258.75
Three runs	Sept	13⅓	212.30	37.50	6.75	256.55
Three runs	Oct	13⅓	237.60	22.50	6.75	266.85
Three runs	Nov	12¾	264.00	2.70	5.25	271.95
Three runs	Dec	13½	268.40	.90	....	269.30
Thirty one runs	....	138.08	2,259.30	297.60	183.65	2,740.55
Per run	....	4.45	72.881	9.600	5.924	88.405

No. 6.—*Coarse-ore furnace* (*intermittent*)—Continued.

Number of runs.	1882.	Quicksilver, flasks.				Wood burned, cords.	Cost of fuel.	Cost of labor.	Total cost.
		Condensers.	Soot.	Total.	Per cent.				
One run	Jan	105		105		11.00	$63.25	$57.50	$120.75
Two runs	Feb	240	17	257		22.00	126.50	83.00	209.50
Two runs	Mar	262	7	269		27.87½	160.25	82.75	243.00
Two runs	April	334		334		26.75	153.81	103.50	257.31
Three runs	May	498		498		41.12½	236.47	120.00	356.47
Three runs	June	502		502		41.50	240.70	128.50	369.20
Three runs	July	509		509		38.50	223.30	120.00	343.30
Three runs	Aug	409		409		40.66⅔	236.84	126.50	363.34
Three runs	Sept	465		465		42.33⅓	254.00	124.00	378.00
Three runs	Oct	556		556		40.75	244.75	127.00	371.75
Three runs	Nov	581		581		41.00	246.00	126.50	372.50
Three runs	Dec	647		647		40.00	240.00	125.25	365.25
Thirty-one runs		5,108	24	5,132	7.16	413.50	2,425.87	1,324.50	3,750.37
Per run				165.548	7.16	13.339	78.254	42.726	120.98
Per ton of ore				1.873	7.16	.151	.885	.483	1.368

In order to make a comparison of the merits of the different furnace-systems in use at New Almaden, I have given the actual working results of each of them for the year 1882. Thus, the actual results obtained from No. 6 are given in the foregoing table. This was made up from the admirable system of furnace records kept at the *hacienda*. (*a*) Thanks to the Hüttner & Scott furnace, it is no longer necessary to treat *tierras* in the intermittent furnace. If it were necessary to treat a full charge of adobes, this would, according to the results for 1875, add 95 cents per ton to the present cost of $1.37, or nearly 70 per cent. to the present cost of roasting in the intermittent furnace.

CONTINUOUS COARSE-ORE FURNACES.

Furnaces No. 7 *and No.* 9.—This pair of duplicate structures is with some slight improvements of detail the same as the continuous coarse-ore furnaces introduced at Idria, Austria, by Bergrath Exeli, from the model of the old Rumford lime kiln. They are coarse-ore shaft roasting furnaces with exterior firing. The lower half of the furnace is a regular hexagon with abutments at the alternate sides. These abutments contain the fire, ash, and draw pits. Each abutment has on its face a fire door and an ashpit door, which latter also commands the discharge-door for the spent ore. The spent ore, after being drawn from the cooling pit of the shaft into the ashpits, is left there until its fumes are

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a In this connection it should be stated that the ruling prices at New Almaden during 1882 were as follows:

Furnace hands	$1.25 to $2.50 per shift of 12 hours.
Coke (English)	15.00 per ton of 2,000 pounds.
Charcoal	12.00 per ton of 2,000 pounds.
Coal (bituminous)	8.94 per ton of 2,000 pounds.
Wood (pine or oak)	5.75 to $6.00 per cord.

exhausted, and is then drawn into the slag cars through discharge doors. These discharge doors are placed on the side of each of the three abutments, lower down than the ashpit doors.

The upper half of the furnace is cylindrical. It is closed at the top by a flat dome, which contains the charging apparatus in the center. The fumes of the furnace are removed from the vapor chamber at the top of the shaft above the surface of the ore, by means of iron pipes 12 inches in diameter. In No. 9 there are three of these discharge pipes, one of which is placed at the top of the shaft on the side opposite each fireplace. In No. 7 there are in addition three others placed at the top of the shaft, one above each fireplace. By means of short cast-iron pipes, these holes are connected with a cast-iron downtake by means of a rectangular system of pipes which encircles the head of the furnace. These pipes, inclined downward at an angle of 10°, lead into the condensers. To keep the pipes clear of soot, they contain small discs of iron. These discs are moved by iron rods passing through stuffing boxes at the angles of the pipe system. They are only occasionally used, and the piston rods are luted with clay when not in use.

The shaft itself is a cylinder, 6 feet interior diameter, by 11 feet 3 inches high, joined to the frustum of a cone 8 feet deep, contracting to a diameter of 4 feet at the bottom. Along the sides of the cylindrical part of the shaft, opposite each of the fireplaces, are placed a series of four peep holes. These, ordinarily closed gas tight, are used to determine the height of the ore column and its temperature.

The fireplaces and discharges have the details common to well-designed continuous shaft roasting furnaces of this type. The shaft and fireplaces are lined with firebrick; the rest of the furnace is of red brick, with the usual expansion space between.

The entire structure rests on a slightly cone-shaped iron plate which crowns the foundation. This would cause any quicksilver that might permeate the masonry to flow to the center of the furnace bottom, where provision is made for receiving it. Experience shows, however, that this precaution is hardly necessary, as no metal has ever reached it.

The lower half of the furnace is inclosed by cast-iron plates, bolted and cemented with rust joints. The cylindrical part has a jacket of one-eighth inch sheet iron; and a cast-iron top-plate crowns the whole, and makes the furnace vapor tight.

The charging apparatus consists of a combination of devices used in iron smelting, viz., the hanging cylinder, and cup and cone; but, owing to the value and poisonous nature of quicksilver fumes, an additional cylinder and cover, with water or sand joint, is introduced above the other devices. The rod moving the cone passes gas tight through a stuffing box in the center of the cover, and is attached to a balance weight. The cover itself is also attached to balance weights by two chains passing over pulleys. The charging is thus easily effected without exposing the men to the fumes. The cover is lifted; a charge of ore and a little fuel is dumped from the ore car into the hopper, and the cover is lowered into place. The charge is then allowed to warm in the hopper, till it has nearly assumed the temperature of the top. This is done to avoid chilling the fumes and condensing them in the furnace by contact with cold ore. At the proper time, an equal volume of spent ore having been meanwhile drawn below into the ashpits, the cone is lowered and the charge dropped into the furnace. The small quantity of fumes that escapes into the space between the cup and cover is allowed to cool a few minutes, and the cover is again lifted and a new charge is added to the hopper.

The details of construction of these furnaces are throughout excellent; they work admirably, and, although they have been in almost continuous operation for nearly ten years, they have required hardly any repairs.

The mode of operating these furnaces is as follows: When first started for a campaign, they are filled above the level of the fireplaces with spent ore, and then with ore to just below the level of the uppermost peep hole. This level is never exceeded; so that there is always above the level of the ore a vapor chamber, at least 3 feet high, containing 140 cubic feet, in which the fumes collect before passing out of the exit flues. With the ore when charged there is mixed 1½ per cent. of coal, charcoal, or coke, to assist in raising the temperature at the top of the furnace and to keep the ore column more open. A good fire of pine or oak is maintained in each of the three fireplaces. The charge of 1,600 pounds of ore and 24 pounds of coke or other fuel, previously weighed on the ore scale, has been placed in the hopper. As soon as the lower peep hole shows a dull cherry red, a quantity of spent ore is drawn into the ashpits, the new charge is lowered into the furnace, and the hopper is refilled as before described.

The spent ore is allowed to remain in the ashpits, discharging any fumes that may be still retained back again through the fireplace into the furnace. At the end of this period it is drawn through the side doors of the abutments into the "slag" cars. Another charge, equal in volume to the new charge, is again drawn through the discharge holes of the shaft into the ashpit, and then the new charge is dropped from the hopper into the furnace. This series of operations goes on every two hours as long as the campaign lasts.

At this rate, these furnaces roast 9⅗ tons per 24 hours, and, as by actual experiment they hold 21 tons, it takes 52⅕ hours for a charge of ore to pass through the furnace. The capacity of these furnaces might easily be increased by drawing and charging more frequently or in greater quantities, and with poor ores this would be advisable; but with the rich ores (6 to 8 per cent.) now treated in these furnaces, experience has led to the above practice.

The amount of labor required for these furnaces is very small. Two men per shift of 12 hours charge and discharge both of them.

No. 7.—*Granza furnace (continuous).*

1882.	Number of days run.	Granza, tons of 2,000 pounds.	Quicksilver, flasks.				Wood burned, cords.	Coal, coke, charcoal (pounds).	Cost of fuel.	Cost of labor.	Total cost.	Remarks.
			Condenser.	Soot.	Total.	Per cent.						
January	31	297.60	470	28	498	6.40	19.25	Coal, 2,400 Coke, 8,928	$188.32	$140.00	$328.32	
February	28	268.80	441	26	467	6.64	10.625	Coal, 8,400 Coke, 8,064	146.92	105.00	251.92	
March	31	297.60	527	34	561	7.21	17.25	Coal, 1,800 Coke, 8,928	174.20	116.25	290.45	
April	30	288.00	466	19	485	6.44	17.75	Coke, 8,640	166.86	112.50	279.36	
May	31	297.60	505	24	529	6.79	19.25	Coke, 8,928	173.19	116.25	289.44	
June	30	288.00	486	14	500	6.64	18.625	Charcoal, 8,640	168.50½	112.50	281.00½	
July	31	297.60	560	30	590	7.58	19.00	Charcoal, 8,928	148.59½	114.37½	262.97	
August	16	148.80	340	2	342	8.79	10.25	Charcoal, 4,464	78.65	67.50	146.15	Stopped August 7 to 22. Cone fell in furnace. New one put in. Two water-backs put in condensers.
September	30	288.00	443	10	453	6.02	19.00	Charcoal, 8,640	152.88	112.50	265.38	
October	31	291.20	516	0	516	6.77	18.75	Coal, 8,736	152.24	116.25	268.49	
November	30	288.00	484	8	492	6.53	18.50	Coal, 8,640	149.88½	112.50	262.38½	
December	31	297.60	672	0	672	8.63	19.75	Coal, 8,928	158.67	128.12½	286.79½	
	350	3,348.80	5,910	195	6,105	6.97	208.00	Coal, 38,904 Coke, 43,488 Chcl., 30,672 113,064	1,858.91½	1,353.75	3,212.66½	
Per day	1	9.569	....	......	17.443	6.97	.594	Coal, Coke, Chcl., 323.04	5.317	3.868	9.179	
Per ton of ore	......	1	....	......	1.823	6.97	.062	Coal, Coke, Chcl., 33.762	.555	.404	.959	

No. 9.—*Granza furnace (continuous).*

1882.	Number of days run.	Granza, tons of 2,000 pounds.	Quicksilver, flasks.				Wood burned, cords.	Coal, charcoal, coke (pounds).		Cost of fuel.	Cost of labor.	Total cost.	Remarks.
			Condensers.	Soot.	Total.	Per cent.							
January	10 5/12	89.60	74	78	152	....	6.25	Coke,	2,688	$56.10	$41.25	$97.35	Fired 2 p. m., January 21, 1882. Seventy-eight flasks came from cleaning condensers before the run began.
February	28	268.80	425	44	469	6.67	17.62½	Coke,	8,064	149.72	105.00	254.72	
March	31	297.60	524	21	545	7.00	18.37½	Coke,	8,928	172.58	116.25	288.83	
April	30	288.00	480	26	506	6.72	17.75	Coke,	8,640	166.86	112.50	279.36	
May	31	297.60	531	26	557	7.15	19.25	Coke,	8,928	173.19	116.25	289.44	
June	30	288.00	468	16	484	6.42	18.62½	Charcoal,	8,640	168.50½	112.50	281.00½	
July	31	297.60	549	32	581	7.46	19.00	Charcoal,	8,928	148.59½	114.37½	262.97	
August	31	297.60	544	21	565	7.28	19.50	Charcoal,	8,928	151.51	130.00	281.51	
September	30	288.00	458	15	473	6.28	19.00	Charcoal,	8,640	152.88	112.50	265.38	
October	31	297.60	558	13	571	7.33	18.75	Coal,	8,928	152.24	116.25	268.49	
November	30	288.00	539	7	546	7.25	18.50	Coal,	8,640	149.88½	112.50	262.38½	
December	31	297.60	615	......	615	7.90	19.75	Coal,	8,928	158.67	128.12½	286.79½	
	344.42	3,296.00	5,765	299	6,064	7.037	212.37½	Coke, 37,248 Chcl., 35,136 Coal, 26,496	98,880	1,800.73½	1,317.50	3,118.23½	
Per day	1	9.570	....	......	17.606	7.037	.617	Coke, Charcoal, Coal,	287.091	5.228	3.825	9.053	
Per ton of ore	....	....	....	......	1.844	7.037	.064	Coke, Charcoal, Coal,	30.000	.5463	.3997	.946	

Summary of granza furnaces.

	Number of days run.	Granza, tons of 2,000 pounds.	Condensers.	Soot.	Total.	Per cent.	Wood burned, cords.	Coal, charcoal, coke (pounds).	Cost of fuel.	Cost of labor.	Total cost.	Remarks.
Furnace No. 7	350.00	3,348.80	5,910	195	6,105	6.97	208.00	113,064	1,858.91½	1,353.75	3,212.66½	
Furnace No. 9	344.42	3,296.00	5,765	299	6,064	7.037	212.37½	98,880	1,800.73½	1,317.50	3,118.23½	
	694.42	6,644.80	11,675	494	12,169	7.000	420.37½	211,944	3,659.65	2,671.25	6,330.90	
Per ton of ore	....	....	....	......	1.831	7.000	.063	3.189	.5507	.4020	.9527	

The foregoing tables show the actual furnace records of furnaces 7 and 9 for the year 1882. The total amount of ore treated, of quicksilver produced, and the expenses are given; also the expense per day and per ton for each furnace, and the average for both.

In comparing these furnaces with No. 6, it must be remembered that both the former are run with the same amount of labor that would be required for one of them if run singly. If two such furnaces as No. 6 were run together, while it would, of course, take double the labor to charge and discharge them, the same men could fire them both during the whole time of roasting. So, if we should compare two such furnaces as No. 6 with two such as No. 7 or No. 9, or if we compared No. 6 with either No. 7 or No. 9, working alone, we should have a more favorable showing for No. 6 than is here given. As it is, the cost of treating a ton of ore in No. 7 or No. 9, when both are run together, is only 70 per cent. of that of roasting in No. 6 when the latter is run by itself.

CONTINUOUS FINE-ORE FURNACES.

The great importance of finding some economical method of treating the large product of poor smalls produced by the mine has been already explained. Making this ore into adobes would add 70 per cent. to the cost of treatment in furnaces of the type of No. 6, and would double the expense of treatment of these ores in Nos. 7 and 9. The reverberatory furnaces (*Fortschaufelungsöfen*) used at Idria would equally be out of the question, at the high prices for labor and fuel that obtain in California.

We have already traced the gradual growth of the Hüttner & Scott furnace, and sketched the successive stages which the invention has reached. Now, for convenience in description, the furnaces will be taken up in the inverse order, the last built being considered first.

Continuous granzita furnace, No. 1.—The fireplace is arranged for burning wood, and is fed from both ends. An earthenware pipe, 16 inches interior diameter, passes through the condensers, thus cooling them and feeding the fireplace with warm air. From it run also a series of airways, built in the walls of the fireplace and of the ore chambers, thus cooling them and supplying air for the more perfect combustion of the flames. Between the lower air or vapor chamber and the fireplace are the four vertical air chambers into which the furnace is divided. The discharge or draw pits are fitted with counterbalanced doors to retain the dust, and they feed upon an apron, and thence into the waste car. The horizontal dimensions of the furnace, exclusive of the foundations, are 17 feet 6 inches by 25 feet 6 inches. The vertical height from the top of the furnace masonry to the ground line is 36 feet; the foundation goes down 7 feet 6 inches deeper. The two feed hoppers are each arranged with four slide valves moved by levers and pistons working in vapor-tight stuffing boxes. The two vapor discharge pipes are provided with regulating valves, and lead from the last vapor chamber of the furnace to the condensers. All along the vertical wall between the fire chamber and the vapor chamber and the ore chambers are pigeon holes, through which the flames and vapors from the ore pass into the ore chamber and out of it again. The pigeon holes in the fire-chamber walls are cut at the bottom so as to slant with the shelves; those in the vapor chambers are cut across horizontally; but all are so beveled that the ore from the ore chamber and the dust from the gases do not accumulate so as to obstruct them. The former is shed back into the ore chamber, and the latter falls to the bottom of the vapor chambers, whence it is removed at the end of the campaign by doors kept bricked during the run.

In case any obstruction should occur in the pigeon holes, or on the shelves, peep holes are placed in the end walls of the furnace, in the axis of the pigeon holes. These latter are placed in the same line opposite each other, under the extreme ends of each shelf. The peep holes are made of 3-inch gas pipe, set in the masonry wall, and are ordinarily closed by iron plugs luted with clay. When any obstruction occurs, it is thus easily removed by an iron bar introduced through these holes.

The air pipe before mentioned is below the grate bars. Branching from it, and leading to the pigeon holes, are hot-air flues which cool the wall, and help to render combustion complete, thus diminishing the production of soot.

The horizontal length of the ore chambers of this furnace is 11 feet 6 inches, the width of each 25½ inches, and their height 27 feet 3 inches from the roof of the ore chamber to the point of discharge.

The tile shelving of this furnace, as in others of this type, is placed at an angle of 45° with the side walls of the chamber; the details, however, are simpler and cheaper than in the rest, and equally effective. The shelves are placed 30 inches apart vertically, those on one wall being 15 inches above those on the other wall, and at right angles to them. The shelves are made of ordinary fire-clay tiles, 36 inches × 16 inches × 3 inches. Four of these make a length, and allow a 3-inch projection into either end wall. These tiles are not let into the side walls, but are supported at the top by slight abutments which project from the side wall. At the bottom they rest at intervals of 18 inches on ordinary firebricks, which rest, end on, in depressions 1 inch deep, cut into the face of the next lower tile in the opposite wall. These bricks are placed so as to be edge on to the descending column of ore, and have their upper edges beveled to oppose as little resistance as possible to it. As the bricks are 9 inches long, there results an 8-inch shelf slit for the furnace. The whole construction of the shelving is very simple, effective, and comparatively inexpensive.

The discharge of this furnace is arranged by supporting the end of the ore columns of the interior ore chambers directly on the bottom of the draw pit; the ore columns of the exterior ore chambers are supported by cast-iron plates. The latter have in front aprons, which discharge the ore into the lower draw pits, and thence the spent ore from both chambers is raked into the waste cars.

This simple arrangement works very well. The ore lies at its natural slope until it is raked out, when the whole ore column gradually feeds down from bottom to top at the same rate. There are four double discharges on each side of the furnace. These are closed by sheet-iron doors to protect the workmen as much as possible from the hot dust.

Inclined iron plates are placed in the foundations of the furnace to prevent the waste of mercury. This precaution is now always taken in building.

Both fronts—the long sides—of the furnace are the same. From the fire chamber the hot gases pass through the lower third of the ore chambers to the vapor chamber; thence they pass through the middle third of the ore chambers to a second vapor chamber; thence out through the top third of the ore chamber again to a third vapor chamber, and thence out through the sheet-iron pipes to the condensers.

The bottom shelf is made of cast iron to resist the abrasion that comes upon it; it is not as much exposed to heat as are the upper shelves.

Finally are to be mentioned the ore rakes. The New Almaden ore gives no difficulty from fusing or clotting, but occasionally in the winter, or when the ore is quite damp, it is found to cake together on the upper shelves so as to demand more or less barring through the peep holes. To obviate this, Mr. Randol introduced the ore rakes. One of these rakes extends through each of the ore chambers just above the topmost shelves, where the ore enters the furnace from the hoppers. If any caking occurs, a few oscillations of the rake break up the clumps, and the ore descends regularly.

Furnace No. 1 has a capacity of 36 tons per twenty-four hours. Its capacity is greater than that of any other furnace at the works except *tierra* furnace No. 3. When filled with ore, as in working, No. 1 holds 45 tons; hence, at the rate of 36 tons per twenty-four hours, a single charge is in the furnace for thirty hours.

The routine of operations at this furnace is as follows:

The amount of 1 ton by volume (*a*) of the spent ore is drawn alternately from either side of the furnace every forty minutes, or, in all, 2 tons (by

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a The *granzita* and *tierra* ores are not weighed at any of the furnaces, but are estimated by volume. This method, on account of the varying amount of moisture in the ore, probably gives better results than weighing without allowing for the moisture, and is sufficiently exact. The volume of the roasted ores is nearly the same as that of the raw ores in the case of *granzita* and *tierras*. With rich *granza* it is sometimes notably less. In any such case the amount drawn is diminished so as to keep the furnace full. It would not do in such cases to increase the amount or frequency of the charging, as that would lead to a loss of quicksilver. The roasted ores contain a larger proportion of smalls than the raw ores, are more brittle, and have a rusted earthy appearance.

volume) are drawn from the furnace every eighty minutes. As a rule, 250 pounds are taken from each of the eight draw pits on each side of the furnace at the times of drawing; but, if the regular working of the furnace demands it, this quantity is reduced or adjusted, so that all shall be thoroughly roasted. The "slag men" thus have to draw and wheel to the dump 2 tons of waste every eighty minutes.

Immediately after drawing from one side of the furnace, two carloads of *granzita*, of 1,000 pounds each, and 20 pounds of coal are charged into the furnace from the hopper on the side from which the drawing took place. The hopper is then immediately filled for the next charge, both to warm the ore and to prevent the escape of fumes. Consequently, each of the two hoppers is charged alternately every forty minutes, or in all 2 tons go into the furnace every eighty minutes.

The firing is done every hour, three 4-foot lengths of oak or pine being ordinarily added to each side of the fireplace per hour. The amount varies with the state of the draft, the object being to keep the fireplace at a good cherry red. From 1½ to 1¾ cords of wood are burned per twenty-four hours, according to whether an auxiliary fire is made in the flue or not.

When No. 1 furnace is worked alone the labor required is as follows: One charger, at $2.50 per 12-hour shift; two slag or fire men, at $1.25 each per 12-hour shift.

In addition, the labor of two men at $1.25 per day, who tram ore across from the ore chutes to the furnace, is charged to it part of the time. Besides firing the furnace and discharging the ore, the fire and slag men pile the fuel, send the ore up the elevator to the charger, and assist the weigher in weighing the quicksilver and tightening the flask stoppers.

The results of this furnace for 1882 are given in the table on page 523.

Continuous granzita furnace, No. 2.—Its construction and mode of operation are similar to those of No. 1. But, having only two ore chambers, its maximum capacity is only half that of the former; its discharging arrangement is simple also, owing to the small number of ore chambers.

The hoppers on top of this furnace are, as in No. 1, divided into compartments, so as to permit more control over the operation of the furnace. These compartments are charged with 1,000 pounds of ore (when in full operation) every forty minutes, alternating with each other. This would make the working capacity of the furnace 18 tons per twenty-four hours. As in No. 1, the drawing precedes the charging. In drawing, 250 pounds are taken from each of the two end draw pits on each end of the furnace, or 1,000 pounds (volume) at a time. The drawings, from either end of the furnace, alternate with each other every forty minutes.

No fuel is charged with the ore of No. 2, but, instead, coal is used in the fireplace. The consumption of fuel is ¾ cord of wood and 500 pounds of coal per twenty-four hours.

No. 1.—*Granzita furnace* (*continuous*).

1882.	Number of days run.	Granza (*a*), tons.	Granzita, tons.	Total ore, tons.	Quicksilver, flasks.				Wood burned, cords.	Coal or charcoal, pounds.	Cost of fuel.	Cost of labor.	Total cost.	Remarks.
					Condensers.	Soot.	Total.	Per cent.						
January	......	....	....	....	....	113	113	....	....	....	....	....	....	Cleaning up condenser.
February	......	....	....	....	....	54	54	....	....	....	....	....	....	
March	......	....	....	....	....	....	....	....	....	....	....	....	....	
April	26	43.50	661.00	704.50	157	....	157	0.85	34.50	*c*13,800	$260.05	$218.90	$478.95	No Hg for ten days from con.
May	31	57.75	1,070.50	1,128.25	394	14	408	1.38	51.50	*c*22,180	391.50	310.00	701.50	
June	30	54.50	1,044.00	1,098.50	350	22	372	1.29	49	*c*21,600	377.08	300.00	677.08	
July	31	94.50	1,028.00	1,122.50	292	20	312	1.06	50.50	21,880	386.98	310.00	696.98	
August	31	30.75	1,095.50	1,126.25	425	33	458	1.59	50.25	22,320	387.43	310.00	697.43	
September	30	42.00	1,052.00	1,094.00	436	9	445	1.56	49.25	21,600	392.70	300.00	692.70	
October	31	87.75	1,057.50	1,145.25	563	24	587	1.96	51.75	22,320	410.94	381.00	791.94	
November	5	15.00	157.00	172.00	335	33	368	*b*8.134	8	3,340	63.03	56.88	119.91	
December	......	....	....	....	....	....	....	....	....	....	....	....	....	Not running.
	215	425.75	7,165.50	7,591.25	2,952	322	3,274	1.664	344.75	149,040	2,669.71	2,186.78	4,856.49	
Per day	1	1.98	33.328	35.308	13.73	1.50	15.23	1.664	1.603	693.209	12.417	10.171	22.588	
Per ton of ore	......	....	....	....	....	....	.431	1.664	.0455	19.633	.352	.288	.640	

a Really *granzita* proper, *i. e.*, screenings of *granza* from *hacienda* ore bins. *b* Clean-up 257 flasks, 33 soot. Twenty-two days' work. *c* Charcoal, rest coal.

No. 2.—*Granzita furnace (continuous).*

1882.	Number of days run.	Granza screenings, tons.	Granzita, tons.	Total ore, tons.	Quicksilver, flasks.				Wood burned, cords.	Coal or charcoal, pounds.	Cost of fuel.	Cost of labor.	Total cost.	Remarks.
					Condensers.	Soot.	Total.	Per cent.						
January	31	48. 00	372. 00	420. 00	270	....	270	2. 45	28. 50	*a* 14, 000	$226. 46	$232. 50	$458. 96	
February	28	83. 25	252. 75	336. 00	262	....	262	2. 98	25. 25	*a* 14, 000	207. 76	210. 00	417. 76	
March	31	48. 75	363. 25	412. 00	316	....	316	2. 93	23 87½	*a* 15, 500	206. 56	232. 50	439. 06	Low percentage of granza screenings.
April	30	35. 25	378. 50	413. 75	261	8	269	2. 48	21. 37½	*a* 15, 000	189. 96	151. 10	341. 06	
May	31	....	372. 00	372. 00	126	....	126	1. 29	24. 37½	*a* 15, 500	206. 80	155. 00	361. 80	
June	30	....	360. 00	360. 00	127	8	135	1. 43	22. 75	*a* 15, 000	196. 45	150. 00	346. 45	
July	31	7. 50	360. 50	368. 00	98	6	104	1. 08	23. 37½	15, 500	203 67	155. 00	358. 67	
August	31	5. 25	368. 50	373. 75	147	5	152	1. 55	23. 12½	15, 500	200. 78	155. 00	355. 78	
September	30	7. 50	355. 00	362. 50	143	18	161	1. 70	23	15, 000	205. 50	150. 00	355. 50	Stopped. Seven flasks. Rest cleaned up.
October	2	4. 50	16. 00	20. 50	82	....	82	1. 53	1. 50	1, 000	13. 50	12. 50	26. 00	
November	......	....	....	....	2	....	2	.....	....	....	....	....	....	Not running.
December	......	....	....	....	....	3	3	.....	....	....	....	....	....	Not running.
	275	240. 00	3, 198. 50	3, 438. 50	1, 834	48	1, 882	2. 09	217. 12½	136, 000	1, 857. 44	1, 603. 60	3, 461. 04	
Per day	1	. 873	11. 631	12. 504	6. 669	. 175	6. 844	2. 09	. 789	494. 546	6. 754	5. 831	12. 586	
Per ton of ore	......	....	....	1	....	....	. 547	2. 09	. 0631	39. 551	. 5401	. 466	1. 006	

a Coal.

When No. 2 furnace is run alone there are employed: One charger and two fire or slag men per 12-hour shift, or six in all per twenty-four hours. When No. 1 and No. 2 are both in operation at the same time labor is economized by running them with the same force. For this purpose are assigned one charger, at $2.50 per 12-hour shift; four slag or fire men, at $1.25 per 12-hour shift. In addition, two men are employed part of the time to bring the ore from the chutes to the furnace bins.

Furnace No. 2 is not always run up to its full capacity, only enough ore being run through it to make up the desired monthly production.

The results for the year 1882 are given in the foregoing table.

TIERRA FURNACES.

Furnace No. 3.—This is arranged on the same general plan as Nos. 1 and 2, but is an earlier construction. It has three pairs of ore chambers, placed side by side. This fact necessitates a different discharging arrangement from that used in Nos. 1 and 2. As previously stated, the two outer pairs of ore chambers for roasting *tierras* have 3-inch shelf slits, while the inner pair, originally intended for granzita, have 5-inch shelf slits. They are now all used, without alteration, for roasting *tierras.*

The feed hoppers, fireplace, pigeon-hole walls, vapor chambers, and ore rakes are entirely similar to those of furnace No. 1, and need no further remark. The discharging arrangements, however, merit further description. Beneath each pair of ore chambers a discharge pit is arranged to contain the "slag" cars, which are run in from a track on the floor of the works. The whole furnace rests on the usual inclined cast-iron plates, in which are discharge slits for each pair of ore chambers; the outside ones are 3 inches and the middle one is 5 inches wide, and they run the whole length of the ore chambers. Immediately beneath each of these slits is its discharge apron. This apron is a cast-iron girder, flat on top, and three times as wide as the slit above it. It rests at either end on rollers running on T rails, at right angles to its length. Each of these aprons is connected with a lever arm outside of the furnace, by means of which a gentle oscillating motion may be given to it.

When the apron is in its central position the foot of the ore column rests upon it, and runs out at its natural slope to each edge of the apron, and the whole ore column in the chamber above is maintained in equilibrium. As soon, however, as an oscillating motion is given to the apron, the ore resting upon it is discharged in a shower from either edge of the apron into the car beneath, and the ore in both chambers, from bottom to top, descends.

The partition wall in each pair of ore chambers rests upon a hollow cast-iron girder. As originally constructed, the space below this girder was entirely free to the passage of ore from either chamber. But with this construction it was found that if in discharging the ore either chamber of the pair got the start of that in the other the velocity of the descending ore on that side would be great enough to impede the discharge from the other side. This difficulty was obviated by Mr. Randol, who introduced a vertical iron plate bolted on to the middle of the hollow girder. In the outside pairs of chambers these plates reach to within 3 inches and in the middle pair to within 5 inches of the discharge slits. This improvement entirely obviated the difficulty, and the discharge of this furnace is now effected with perfect ease and regularity.

The setting of the tile shelving in this furnace and in No. 8 also differs somewhat from that of Nos. 1 and 2. The tiles are of peculiar shape, and were made to order for the furnace at Staten island, New York. Those for the *tierra* chambers were made $20\frac{7}{16}$ inches wide on the upper face, while those for the *granzita* have a width of only $18\frac{7}{16}$ inches. Both are 3 inches thick. All of them were made with a square lug or shoulder, $5\frac{1}{2}$ inches thick, and forming an angle of 45° with the face of the shelf. The width of the lugs on their upper face was made $4\frac{9}{16}$ inches or $6\frac{3}{4}$ inches, according to the thickness of the partition wall between the chambers. The wall between each two pairs of ore chambers was made $13\frac{3}{4}$ inches thick, and between the two chambers of each pair only $9\frac{1}{4}$ inches. Two shelves, projecting into adjacent chambers, are set with their shoulders abutting against each other, allowing for $\frac{1}{4}$-inch to $\frac{1}{8}$-inch joints. Consequently, the shelves form an integral part of the partition walls. Beneath the shoulders of the two shelves is set another tile, also $5\frac{1}{2}$ inches thick. This has the form of a frustum of a wedge whose faces are at right angles to each other. This tile also forms an integral part of the partition wall, and projects out into either chamber so as to support the shelves from beneath for half their width. Beneath the supporting tiles are four tiers of firebrick, then the next pair of abutting shelf lugs and their supporting tiles, and so on. The ore chambers are $22\frac{3}{8}$ inches wide, and the shelves in each wall are 21 inches apart vertically. This method of setting has given good results, but the method now used in the latter constructions is to be preferred on account of cheapness and simplicity.

In this furnace the fireplace is placed 5 feet above the discharge opening, and the air to supply the fire is drawn through the hot ore below the level of the grates, so that the ore reaches the apron free of fumes, and cooled to such a temperature that it may be easily handled. In Nos. 1 and 2 the fireplace is nearly on a level with the discharge openings, and the ore cools mainly in the draw pits.

Furnace No. 3 is entirely inclosed by a sheathing of heavy iron plates, bolted and cemented, with rust joints.

The normal capacity of this furnace is 36 tons, the same as that of No. 1. The furnace holds, when under working conditions, 51 tons of ore; a charge is, therefore, thirty-four hours in the furnace.

The routine of operations at this furnace is as follows: The aprons or shaking tables under each of the three pairs of ore chambers are oper-

No. 3.—*Triple tierra furnace (continuous).*

1882.	Number of days run.	Tierras, tons.	Quicksilver, flasks.				Wood burned, cords.	Coal and charcoal, pounds.	Cost of fuel.	Cost of labor.	Total cost.	Remarks. (Three pairs of ore chambers.)
			Condensers.	Soot.	Total.	Per cent.						
January	31	1, 116. 00	425	......	425	1. 46	57. 00	23, 000	$430. 56	$387. 50	$818. 06	Started October 12, 1881.
February	28	1, 008. 00	411	......	411	1. 55	47. 00	*a* 28, 000	395. 41	350. 00	745. 41	
March	31	1, 116. 00	387	......	387	1. 32	49. 25	*a* 31, 000	421. 76	387. 50	809. 26	
April	30	1, 080. 00	350	9	359	1. 27	46. 75	*a* 30, 000	402. 91	375. 00	777. 91	
May	31	1, 116. 00	309	7	316	1. 08	46. 625	*a* 31, 000	401. 39	387. 50	788. 89	
June	30	1, 080. 00	314	6	320	1. 13	45. 00	*a* 30, 000	390. 00	375. 00	765. 00	
July	31	1, 116. 00	351	26	377	1. 29	47. 50	31, 000	408. 80	387. 50	796. 30	
August	31	1, 116. 00	301	13	314	1. 08	47. 00	31, 000	405. 90	387. 50	793. 40	
September	30	1, 080. 00	461	24	485	1. 71	45. 583	30, 000	408. 50	375. 00	783. 50	
October	31	1, 116. 00	392	11	403	1. 38	47. 00	31, 000	421. 50	387. 50	809. 00	
November	30	1, 078. 00	372	12	384	1. 36	45. 25	30, 000	406. 50	375. 00	781. 50	
December	......	....	165	33	198	......	....	....	....	....	....	Stopped December 1, 1882.
	334	12, 022. 00	4, 238	141	4, 379	......	523. 958	326, 000	4, 493. 23	4, 175. 00	8, 668. 23	
Per day	1	35. 994	....	......	13. 11	......	1. 569	976. 048	13. 453	12. 50	25. 953	
Per ton of ore	......	1	....	......	. 459	......	. 044	27. 117	. 374	. 347	. 721	

a Coal.

ated at intervals of ten or fifteen minutes, so as to discharge from each 1 ton (by volume) every two hours. After the ore has descended in the various chambers, subsequent to discharging below, 1 ton of ore is added to each of the three ore hoppers at intervals of forty minutes; *i. e.*, each hopper receives 1 ton every two hours. The firing and tramming of the spent ore goes on meanwhile as at the other furnaces.

The fuel required at this furnace is 2½ cords of wood per 24 hours, if that alone is used; but if coal is used, the amount of wood is reduced in proportion. The working force is: Two men, at $2.50 per 12 hour shift; one man, at $1.25 per 12-hour shift.

The campaign for 1882 is shown in the preceding table.

Furnaces No. 4 *and No.* 5.—Furnace No. 4, one of the old intermittent furnaces, is now torn down. No. 5, the first experimental form of the Hüttner & Scott, still exists. As already stated, this furnace at first had a capacity of only 6 tons. It was afterward enlarged so as to handle 12 tons. In this shape it gave excellent results, as far as good roasting was concerned, but on account of its smaller size it was not so economical of labor and fuel as the larger ones, and is now seldom used.

Furnace No. 8.—This *tierra* furnace completes the list of the fine-ore furnaces. This furnace is really two separate furnaces, like No. 5, on a larger scale, united in one structure. Each furnace contains a pair of ore chambers, its own fireplace and vapor chambers and exit flues, entirely distinct from those of the other. These two structures stand united, end to end; the fireplace at the outside, and the exit flues and vapor chambers opposite the fireplaces, side by side, in the middle. As a consequence, there results a long, high, and narrow structure, 37 feet by 9 feet 5 inches on the ground plan by 41 feet total height above the ground line.

The setting of the tiles is like that of No. 3. The ore chambers are a little narrower, being 18 inches wide by 8 feet 8 inches long, and 30 feet 9 inches high, from the discharge slit at the bottom to where the ore enters at the top. The fireplaces are 3 feet above the discharge, so that the lower part of the furnace acts as a cooling chamber. The last discharge tile is made of cast iron. This furnace is iron-clad, and, like No. 3, is a beautiful piece of work.

The location of the furnace in the works and its shape necessitate an arrangement for discharging different from that of No. 3, although it operates on the same principle. The two ore chambers are in the same plane, that of the horizontal and vertical axes of the furnace, and discharge through 3-inch ore slits, as in No. 3 furnace. Beneath each of them is placed an apron, or shaking table, like those of No. 3. But instead of resting on rollers, as in the latter, they are carried by a heavy frame of cast iron shaped like the letter H. The feet of this frame rest in the bearings, which allow the same oscillating motion that would be given by the rollers. The connecting bar of the H piece is below the level of the floor of the works, and above it is a fixed platform with rails, on which is borne a low truck, with rails upon it, at right angles to those on which it runs. By means of this device a long slag car (7 feet long) may be run sidewise from the floor of the works on to the platform above the **H** piece directly under the discharge apron. By means of levers, a slight oscillating motion may now be given to the **H** piece, and to the apron which it carries. As a consequence, the ore is discharged in a shower from either edge of the apron into the car, just as in No. 3 furnace. While drawing either of these furnaces the draw pits are closed to keep in the dust.

The normal capacity of No. 8 is 24 tons per 24 hours. When full it holds 32 tons; consequently a charge stays in the furnace 32 hours.

The hoppers of each pair of chambers receive each a charge of 1,000 pounds per hour, or the double furnace receives 1 ton per hour. The hoppers are charged alternately. The discharge is effected by the shaking table, as in No. 3, by working it every 10 or 15 minutes.

Two cords of wood are burned per 24 hours, and the working force of the furnace is: One man at $2.50 per 12-hour shift; one man at $1.25 per 12-hour shift.

The campaign for 1882 appears in the table on page 530.

The saving effected by the Hüttner & Scott furnaces may now be readily calculated. If they were not in use, the old intermittent furnaces being used in their stead, and the ore being made into *adobes*, we should have, per ton:

Cost of roasting in intermittent furnace	$1.368
Cost of making *tierras* and *granzita* into *adobes*	.500
Cost of handling *adobes*	.450
Total cost per ton	2.318
26,688.25 tons at $2.318	61,863.364
Present actual cost in Hüttner & Scott furnaces	20,031.850
Annual saving	41,831.514

If, instead of treating these ores in the intermittent furnaces, the *adobes* were roasted in the monitors, we should have, per ton:

Cost of roasting in No. 7 and 9 furnaces	$0.953
Making and handling *adobes*	.950
Total cost per ton	1.903
26,688.25 tons at $1.903	50,787.74
Present actual cost in Hüttner & Scott furnaces	20,031.85
Annual saving	30,755.89

Instead of making the *granzita* into *adobes*, this might be in part roasted directly in the coarse-ore furnaces, and the latter might be made to work faster than with rich *granza*. These modifications might slightly reduce the above saving; but the difference would be slight. In making this comparison, the interest on the furnace plant has not been mentioned.

No. 8.—*Double tierra furnace (continuous).*

1882.	Number of days run.	Tierras, tons.	Quicksilver, flasks.				Wood burned, cords.	Coal burned.	Cost of fuel.	Cost of labor.	Total cost.	Remarks.
			Condensers.	Soot.	Total.	Per cent.						
January	......	....	....	69	69	....	....	....	....	....	....	Closed for repairs and cleaning up. Afterward not started till needed.
February	......	....	....	4	4	....	....	....	....	....	....	
March	......	....	....	....	....	....	....	....	....	....	....	
April	......	....	....	....	....	....	....	....	....	....	....	
May	......	....	....	12	12	....	....	....	....	....	....	Fired July 11, 1882. No Hg for seven days.
June	......	....	....	5	5	....	....	....	....	....	....	
July	20¼	425.00	49	....	49	.44	41.00	....	$237.80	$140.00	$377.80	Stopped September 25, 1882. Eighty-nine flasks cleaned up.
August	31	744.00	192	....	192	.99	62.333	....	361.54	232.50	594.04	
September	24¾	585.00	284	....	284	1.86	50.583	....	303.50	185.00	488.50	Fired 6 p. m., October 12, 1882. Ten flasks cleaned previous to firing.
October	18¼	420.00	129	....	129	1.17	38.25	....	229.25	138.75	368.00	
November	30	718.50	243	3	246	1.31	60.25	....	361.50	225.00	586.50	
December	31	744.00	244	....	244	1.25	62.50	....	375.00	256.25	631.25	
	155¼	3,636.50	1,141	93	1,234	1.298	314.916	....	1,868.59	$1,177.50	3,046.09	
Per day	1	23.424	....	....	7.949	1.298	2.028	....	12.036	7.584	19.620	
Per ton of ore	......	....	....	....	.339	1.298	.086	....	.514	.323	.837	

Résumé of granzita and tierra furnaces (production and cost).

Furnaces.	Number of months run in 1882.	Number of days run.	Granza screenings, tons.	Tierras and granzita, tons.	Total ore, tons.	Quicksilver, flasks.				Wood burned, cords.	Coal, etc., pounds.	Cost of fuel.	Cost of labor.	Total cost.
						Condenser.	Soot.	Total.	Per cent.					
No. 1	7	215	425. 75	Gr. 7, 165. 50	7, 591. 25	2, 952	322	3, 274	1. 664	344. 75	149, 040	$2, 669. 71	$2, 186. 78	$4, 856. 49
No. 2	9	275	240. 00	Gr. 3, 198. 50	3, 438. 50	1, 834	48	1, 882	2. 09	217. 125	136, 000	1, 857. 44	1, 603. 60	3, 461. 04
No. 3	11	334	....	Tr. 12, 022. 00	12, 022. 00	4, 238	141	4, 379	1. 39	523. 958	326, 000	4, 493. 23	4, 175. 00	8, 668. 23
No. 8	6	155. 25	....	Tr. 3, 636. 50	3, 636. 50	1, 141	93	1, 234	1. 298	314. 916	....	1, 868. 59	1, 177. 50	3, 046. 09
Totals	......	979. 25	665. 75	26, 022. 50	26. 688. 25	10, 165	604	10, 769	1. 543	1, 400. 749	611, 040	10, 888. 97	9, 142. 88	20, 031. 85
Average per ton of granzita and tierras	......	....	....	....	....	....	......	. 4035	1. 543	. 052	22. 895	. 408	. 343	. 751

Résumé of costs per ton, granzita aud tierra furnaces.

Furnaces.	Quicksilver, flasks.		Wood burned, cord.	Coal, etc., pounds.	Cost of fuel.	Cost of labor.	Total cost.
	Total.	Per cent.					
Furnace No. 1 (*a*), capacity 36 tons per 24 hours	. 431	1. 664	. 0455	19. 633	$0. 352	$0. 288	$0. 640
Furnace No. 2 (*a*), capacity 12 tons per 24 hours	. 447	2. 09	. 0631	39. 551	. 5401	. 466	1. 006
Furnace No. 3, capacity 36 tons per 24 hours	. 459	....	. 0440	27. 117	. 374	. 347	. 721
Furnace No. 8, capacity 24 tons per 24 hours	. 339	1. 298	. 086	....	. 514	. 323	. 837

a In working Nos. 1 and 2 the labor of tramming the ore from the chutes to the furnaces has been included. The low cost of working No. 1 is partly due to the fact that Nos. 1 and 2 are usually worked together. No. 2 was not worked to its full capacity. The advantage of increasing the capacity of these furnaces is evident from the table

Summary of all the furnace records.

Furnaces.	Number of days run.	Granza, tons.	Terrero, tons.	Tierra and granzita, tons.	Total ore, tons.	Quicksilver, flasks.				Wood, cords.	Coal and charcoal, pounds.	Cost of fuel.	Cost of labor.	Total cost.
						Condensers.	Soot.	Total.	Per cent.					
Granzita and tierra.	979. 25	*a* 665. 75	....	26, 022. 50	26, 688. 25	10, 165	604	10. 769	1. 543	1, 400. 749	611, 040. 00	$10, 888. 97	$9, 142. 88	$20, 031. 85
Granza	694. 42	6, 644. 80	....	....	6, 644. 80	11, 675	494	12, 169	7. 000	420. 375	211, 944. 00	3, 659. 65	2, 671. 25	6, 330. 90
Intermittent........	*b* 138. 08	2, 259. 30	297. 60	183. 65	2, 740. 55	5, 108	24	5, 132	7. 160	413. 500	....	2, 425. 87	1, 324. 50	3, 750. 37
	1, 811. 75	9, 569. 85	297. 60	26, 206. 15	36, 073. 60	26, 948	1, 122	28, 070	2. 976	2, 234. 624	822, 984. 00	$16, 974. 49	$13, 138. 63	$30, 113. 12
Per ton of ore......	....	....	....	....	1	....	....	. 980	2. 976	. 619	22. 814	. 4705	. 3642	. 8347
The total cost of cleaning condensers and working soot from all furnaces was $2,509.85, or per ton of ore														. 0664
Total direct cost of working one ton of ore........														. 9011

a *Granza* screenings, *i. e.*, rich *granzita*.

b Firing time only.

In concluding this account of the Hüttner & Scott furnaces, it may be said that they fulfill every requirement of a good roasting furnace. They utilize the principle of opposed currents; they allow the ore to cool in the furnace itself before it is drawn, thus utilizing the heat and removing the last traces of quicksilver. The stirring of the ore is entirely automatic and very thorough; for each time the ore passes from one shelf to the next opposite one, the ore, which lay at the bottom of the layer, next to the surface of the upper shelf, and out of contact with the air, is on the next lower shelf brought to the surface, where it is directly exposed to oxidation. This operation is repeated from 20 to 30 times, according to the number of shelves in the chamber. The feeding and discharge of ore and waste is effected with a minimum of labor and without the use of power. Add to this that the whole operation is under perfect control, and may be modified at any time, according to the nature of the ore, without stopping the regular operation of the furnace; and also, that the repairs are mostly slight and inexpensive, and we have a very good showing for the furnace.

The ores of New Almaden cannot be regarded as difficult to roast, and the results obtained with this furnace might be thought not to apply to other ores. The fine ores at the Sulphur Bank quicksilver mine, however, present many difficulties. Thus at times they contain alkaline borates, and so frit to a pasty mass; at other times the lumps, decrepitate in the furnace to a dust as fine as ashes; this, when red hot, runs almost like water. After much difficulty with other furnaces, the Hüttner & Scott furnace was introduced there, and gave excellent results. It is not improbable that this furnace could be used with advantage in roasting fine ores of other metals. Those which are not too fusible could probably be treated in it with success.

The preceding summary gives the results of the year's run of all the furnaces for 1882.

During the year 1883 the furnaces were in operation as follows:

No. 6 made 27 runs.

Nos. 7 and 9 worked continuously 365 days.

No. 1 ran 286 days.

No. 2 ran 253 days.

No. 3 ran 188 days.

No. 8 worked 352 days, and was stopped only for lack of dumping-room.

The production was even greater than for 1882, the total amount treated for 1883 being:

	Tons of 2,000 pounds.
Granza	10,428.40
Terrero	185.35
Granzita and tierras	27,967.50
Total	38,581.25

The product of quicksilver for the year was 29,000 flasks at 76½ pounds, or a yield of 2.875 per cent.

Finally, in concluding the present paper, the best idea of the increased efficiency of the new furnace plant may be gathered from the recent great increase in the amount of ore annually reduced. Thus, in the year from July, 1850, to July, 1851, there was reduced less than 2,500 tons of ore, an amount less than one-fifteenth that of 1883. From 1850 on, the quantity annually reduced increased, with some interruptions, until in 1776 it rose to nearly 17,000 tons. Since then, that is during the seven years ending with 1883, this amount has been more than doubled. This great increase has been, of course, mainly due to the introduction of the new furnaces, which allowed the treatment of large quantities of low-grade ores that formerly could not be handled at a profit.

The percentage yield of the ores treated has gradually decreased from 36.74 per cent. in 1850–'51 to 2.875 per cent. in 1883. This reduction in the content of the ore is, however, partly due to the great increase in the amount of low-grade ores now treated, although the richest ores now run only as high as 6 or 8 per cent., as against 36.74 per cent. in 1850.

The greatest annual yield of quicksilver since records have been kept (since 1850) occurred from 1861 to 1866, when the rich Ardilla and Santa Rita *labores* were being worked. The highest annual yield of the mine now on record was in 1865, when it produced 47,194 flasks. The quicksilver product then declined till, in 1874, it had sunk to 9,084 flasks, an annual yield, however, that has been exceeded by only three other mines in California. From 1874 to the close of 1883, owing to constant improvements in the furnace plant, the annual yield has steadily increased, almost without interruption, till in 1883 it reached 29,000 flasks, the highest product since 1866.(*a*)

Miscellaneous statistics of the New Almaden mine.—The following tables, which explain themselves, give the labor account and enumerate the machinery of the mine, with analyses of the cost of mining, for the month of October, 1884. The figures have been kindly furnished from the company's books.

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a Professor Christy's paper ends here.

Analyses of New Almaden mine pay roll, October, 1884, *showing average wages earned per day in the various departments.*

Items.	Number of days worked.	Earnings.	Less mining materials purchased by miners.	Net earnings.	Average earnings per day.
Office and surveying	119	$477 00	....	$477 00	$3 99
Machinists and helpers	132	439 77	....	439 77	3 33
Engine drivers	336	840 00	....	840 00	2 50
Firemen	242	405 00	....	405 00	1 67
Blacksmith	217	420 61	....	420 61	1 94
Blacksmith's helpers	254	244 09	....	244 09	96
Carpenters	87	253 75	....	253 75	2 91
Laborers in "labores"	524	1, 143 50	$76 30	1, 067 20	2 03
Surface laborers	799	1, 582 19	....	1, 582 19	1 98
Laborers cleaning granza and handling tierras	798¾	1, 277 49	....	1, 277 49	1 60
Timbermen and shaftmen, including mining captain and foremen	509	1, 510 00	....	1, 510 00	2 95
Blasters	215	565 37	....	565 37	2 63
Tramming on day's pay	179	402 75	....	402 75	2 25
Tramming by contract	594	1, 489 21	76 00	1, 413 21	2 38
Drilling by the foot	2, 337	6, 337 29	320 00	6, 017 29	2 57
Miners on yardage contracts	1, 842½	6, 092 62	680 25	5, 412 37	2 93
Skip filling	260	699 40	35 65	663 75	2 56
Miners on tribute	408	702 87	52 00	650 87	1 59
Surface mining	502	749 25	....	749 25	1 49
Pumpmen and landers at shafts	285	653 00	....	653 00	2 29
Transportation by teams; contract per ton	....	770 79	....	770 79	....
Total	10, 640½	27, 055 95	1, 240 20	25, 815 75	....
Less transportation	....	770 79	....	....	....
		26, 285 16	....	....	....
Average per day of whole	....	....	....	....	2 47

Machinery in use and on hand, New Almaden mine, October, 1884.

Location.	Description.	Number machines.	Number boilers.
Randol shaft	Hoisting engine	1	3
	Machine shop engine	1	....
	Feed-pump engines for boilers	2	....
Santa Isabella shaft	Pumping engine	1	4
	Hoisting engine	1	....
	Air compressor	1	....
	Fire engine	1	....
	Feed engine for boilers	2	....
Washington shaft	Pump engine	1	2
	Hoisting engine	1	....
	Air compressor	1	....
	Feed engine for boilers	2	....
	Pump to force water from springs to tank	1	1
	Ingersoll air drills	4	....
Buena Vista shaft	Pump engine	1	6
	Hoisting engine	1	....
	Hoist for pump works	1	....
Miscellaneous	Compressor	1	....
	Feed engine for boilers	2	....
	Ingersoll air drills	5	....
	Hoist engine in mine	1	....
	Small engines for fans in mine	3	....
	Engine to run soot pans at hacienda	1	2
	Total	36	18

Cost per ton for extracting rock ore from New Almaden mine, October, 1884.

Total mine pay roll		$27,055.95
Less surface mining, cleaning ore, and transportation		2,797.53
		24,258.42
Rock of all description hoisted from mine (tons)		9,503.35
Cost per ton for deep mining, $2.55, distributed as follows:		*Per ton.*
Office	$677.00	$0.071
Machinery and pumping	2,337.77	.246
Mechanics	918.45	.096
Surface labor	1,582.19	.166
Tramming and skip filling	2,568.86	.273
Timbermen and shaftmen	1,310.00	.137
Excavating rock, etc., from mine	14,864.15	1.564
	24,258.42	2.553
Surface mining (open cut and old dump)	749.25	
Cleaning ore and transportation	2,048.28	
Complete labor cost per ton, including surface mining	27,055.95	2.508
Average supplies cost	6,400.00	.592
Grand total cost per ton, including cost of supplies used (estimated from average consumption of previous years)	33,455.95	3.100
Terrero and tierras ore (tons)	1,283.50	

Analysis of New Almaden hacienda pay roll, October, 1884, *showing average wages earned per day in the various departments.*

Items.	Number of days worked.	Earnings.	Average per day.
Office (including superintendent's salary)	120½	$790.85	$6.59
Masons	42	179.00	4.26
Foreman and weighers	93	270.00	2.903
Carpenters	54	162.00	3.00
Blacksmith and helper	53	132.00	2.49
Machinist	27½	45.00	1.638
Stable	31	75.00	2.419
Cartmen	81½	101.75	1.248
Laborers	253	436.56	1.73
Furnace and soot	509	1,181.00	2.32
Chinese labor	701½	871.52	1.243
Total	1,965½	4,244.68	2.159
Railroad incline contract by ton	....	264.91	....
Total pay roll	....	4,509.59	....

NICKEL.

BY W. P. BLAKE.

Production.—The only metallic nickel now made in the United States is produced at the American Nickel Works at Camden, New Jersey, opposite Philadelphia, by Mr. Joseph Wharton. These works, which suspended operations at the close of the year 1882, were started again in 1883, but did not reach full activity until October, 1884. In 1883 and 1884 the ore treated was exclusively from the Gap mine, Lancaster county, Pennsylvania. The production of the works since 1876, including the nickel contained in copper-nickel alloy, was as follows:

Annual production of nickel in the United States from and including 1876.

Years.	Pure grain nickel.	Nickel contained in copper-nickel alloy.	Total.	Average price per pound.	Value.
	Pounds.	*Pounds.*	*Pounds.*		
1876			201,367	$2.60	$523,554
1877			188,211	1.60	301,138
1878			150,890	1.10	165,979
1879			145,120	1.12	162,534
1880			233,893	1.10	257,282
1881			265,668	1.10	293,235
1882	277,034	4,582	281,616	1.10	309,777
1883	6,500	52,300	58,800	.90	52,920
1884		64,550	64,550	.75	48,412
Total			1,590,115	1.33	2,113,831

It is impossible to state the quantity of nickel salts produced in the United States annually. They are made by several different establishments. The quantity is estimated to be from 15,000 to 25,000 pounds.

The nickel deposits of the Pacific slope have not yielded more than experimental shipments to European refiners. The silicated ores of Douglas county, Oregon, similar in their nature to those of New Caledonia, but of lower grade in metal, are believed to exist in large quantity though scattered over a considerable area. At the present prices for nickel these ores are not inviting to eastern smelters. The arsenides of nickel of Churchill county, Nevada, are rich and may prove to be in abundant quantity, but it is yet uncertain how far the veins or deposits may be relied upon for a regular supply.

Consumption.—The greatly increased consumption of nickel which was hoped for as a consequence of the discoveries that made the metal practicably malleable has not been realized. The slow increase of consumption is considered to be due alone to a slightly larger use in the old channels of German silver manufactures, nickel plating, and coinage.

Nickel coinage of the United States.

Calendar years.	One-cent nickel coins.		Three-cent nickel coins.		Fve-cent nickel coins.		Pure nickel consumed.
	Pieces.	Value.	Pieces.	Value.	Pieces.	Value.	
							Troy ounces.
1857	17, 432, 410	$174, 324. 10					313, 931. 92
1858	24, 600, 000	246, 000. 00					443, 731. 22
1859	36, 400, 000	364, 000. 00					637, 687. 87
1860	20, 566, 000	205, 660. 00					391, 199. 20
1861	10, 100, 000	101, 000. 00					181, 076. 48
1862	28, 375, 000	283, 750. 00					505, 320. 42
1863	49, 840, 000	498, 400. 00					895, 878. 04
1864	13, 170, 000	131, 700. 00					237, 049. 00
1865			11, 382, 000	$341, 460. 00			165, 955. 08
1866			4, 801, 000	144, 030. 00	14, 742, 500	$737, 125. 00	674, 553. 54
1867			3, 915, 000	117, 450. 00	30, 909, 500	1, 545, 475. 00	1, 307, 978. 08
1868			3, 252, 000	97, 560. 00	28, 817, 000	1, 440, 850. 00	1, 213, 242. 65
1869			1, 604, 000	48, 120. 00	16, 395, 000	819, 750. 00	688, 017. 22
1870			1, 335, 000	40, 050. 00	4, 806, 000	240, 300. 00	215, 171. 62
1871			604, 000	18, 120. 00	561, 000	28, 050. 00	32, 591. 00
1872			862, 000	25, 860. 00	6, 036, 000	301, 800. 00	215, 303. 32
1873			1, 173, 000	35, 190. 00	4, 550, 000	227, 500. 00	110, 057. 07
1874			790, 000	23, 700. 00	3, 538, 000	176, 900. 00	76, 772. 51
1875			228, 000	6, 840. 00	2, 097, 000	104, 850. 00	21, 135. 36
1876			162, 000	4, 860. 00	2, 530, 000	126, 500. 00	2, 688. 42
1877							
1878			2, 350	70. 50	2, 350	117. 50	132. 90
1879			41, 200	1, 236. 00	29, 100	1, 455. 00	1, 821. 78
1880			24, 955	748. 65	19, 955	997. 75	1, 197. 32
1881			1, 080, 575	32, 417. 25	72, 375	3, 618. 75	10, 505. 16
1882			25, 300	759. 00	11, 476, 600	573, 830. 00	344, 553. 71
1883			10, 609	318. 27	22, 969, 421	1, 148, 471. 05	703, 426. 73
1884			5, 642	169. 26	11, 273, 942	563, 697. 10	399, 141. 37
Total	200, 483, 410	2, 004, 834. 10	31, 298, 631	938, 958. 93	160, 825, 743	8, 041, 287. 15	9, 790, 118. 99

The total annual consumption in the United States is now probably nearly 400,000 pounds. It cannot be ascertained by adding the production of the American Nickel Works to the imports, because in the years 1883 and 1884 the market was supplied in part from the accumulated stock of previous years.

By the tariff of 1883 the duty on nickel ores was reduced from 25 cents per pound to 15 cents per pound, and the price has fallen from an average of 90 cents per pound in 1883 to an average of 75 cents per pound in 1884.

The European consumption of nickel is now supplied mostly from the importations from New Caledonia, and it is possible that with the low prices ruling the United States market may soon be supplied from the same source.

NEW LOCALITIES OF NICKEL ORE IN THE UNITED STATES.

The occurrences of nickel ore in this country were described in detail in "Mineral Resources, 1882," page 401 *et seq.*, to which the reader is referred. The principal localities are Lancaster Gap, Pennsylvania; Chatham and other places in Connecticut; Mine la Motte, Missouri; and in California, Nevada, Oregon, Colorado, and New Mexico. The following notes are supplementary merely:

Discoveries of nickel ore in Nevada.—During the past few years numerous discoveries of nickel ores have been reported from various parts of the country, but chiefly in the State of Nevada. Reference was made to some of these discoveries in the report for 1882. Samples of the ore from one of the claims located in Cottonwood cañon, Churchill county, have been analyzed by Prof. S. B. Newberry with the following results: The samples weighed in the aggregate about 30 pounds. The sample from the greatest depth was nearly pure niccolite, which in the upper levels shows the effects of oxidation and hydration. The specimen from the 10-foot level consists entirely of the hydrated arseniate, or annabergite, containing 33.71 per cent. of nickel oxide, 36.44 of arsenic acid, and 24.77 per cent. of water. The source of these ores is near Lovelock's Station, on the Central Pacific railroad, and it is stated that Mr. Lovelock has located twenty-eight claims on the mountain traversed by the veins, and that he has sent a sample lot of 15 tons to San Francisco which averaged 12 per cent. nickel, 7 per cent. cobalt, and 29 per cent. arsenic. A company called the Nevada Nickel Mining Company has been incorporated in California.

Nickel ore in the high Sierra of California.—In October, 1883, discoveries of nickel ore were announced as made in the belt of country lying east of the higher granitic mountains of the Sierra Nevada near Mono lake, and extending from Green creek north of Castle peak to the north fork of Rush creek south of Mount Lyell, a distance of 25 miles. A vein opened on White Wolf mountain 5 miles south of Tioga hill is said to have yielded samples that assayed 34 per cent. of nickel. Nickel ore is also reported from the vicinity of Carisa creek in southern California, near the desert, and at White river in Kern county.

FOREIGN NICKEL (See also 1882 report).

Lower California.—A nickel discovery is announced at Real del Castillo, Baja California, 400 miles southeast of San Diego. One of the veins is said to contain arsenide of nickel yielding masses that assay from 20 to 45 per cent. of nickel. Another carries copper nickel. Emerald nickel is also found. Nickel ore is also reported from near San Rafael.

New South Wales.—A massive variety of copper nickel of a copper-red color, in parts incrusted with pale green nickel hydrate, is reported from near Bathurst. It was found by the Rev. W. B. Clarke on the Peel river and to the southwest of Weare's creek. It is yellowish white in color and highly magnetic.

Great Britain.—The production of cobalt and nickel ore in Great Britain during the year 1882 was 38 long tons, valued at £241. There is a mine of cobalt and nickel in Wales, the Fod Hirradag Cwm Rhyl, which produced 49 tons 9 hundredweights of ore in 1883, valued at the mine at £173, and containing 1.4 per cent. cobalt and 0.7 per cent. nickel. This was the total production of the United Kingdom in that year.

Prussia.—It appears that in 1882 there were seven mines producing nickel ore, and in 1883 five mines. The yield amounted in each year to 14 metric tons.

France.—Thirty metric tons of nickel were made in France in 1882.

RECENT NOTES ON THE METALLURGY OF NICKEL.

Concentrating nickel mattes by the pneumatic process.—The *Engineering and Mining Journal* says: "M. Manhès has recently begun a series of experiments on a small scale in concentrating nickel mattes from the Berg Seljen mines in Norway. The *Génie Civil* tells us that M. J. Garnier, so prominently identified with the development of the famous mines of New Caledonia, and M. G. Salomon brought a lot of 16 per cent. nickel matte from Berg Seljen. Three lots of 50 pounds, melted in a crucible, were run into a converter of the same type as that used for Bessemerizing copper matte, the pressure of the blast being from 350 to 500 millimeters of mercury. The blowing was stopped respectively in five, ten, and fifteen minutes with the following results:

Time.	Copper.	Nickel.	Iron.
First blow:			
Before blowing	5.86	16.30	22.40
After 5 minutes	11.00	30.73	n. d.
Cinder	.05	1.51	n. d.
Second blow:			
Before blowing	5.86	16.94	22.40
After 10 minutes	14.13	50.80	10.00
Cinder	.60	3.00	n. d.
Third blow:			
Before blowing	5.80	16.60	22.40
After 15 minutes	11.30	70.06	1.20
Cinder	.30	4.00	n. d.

"So far as they go, the results are decidedly encouraging. They clearly indicate that it is not a very difficult matter to concentrate low-grade nickel mattes into a product of such high tenor in nickel that they can go directly to the refining processes. On one vital point, however, the experiments furnish no data. The material worked with is called a 'matte,' and from its origin we judge that it carries little arsenic. It remains to be seen in what manner arsenic behaves in the converter. If it obstinately clings to the metal, the advantages of a rapid and cheap concentration would probably be outbalanced by the drawbacks incident to the presence of arsenic in great quantity in later operations."

Phosphorus in nickel.—Pure nickel, after melting and casting, generally holds a greater or less quantity of oxygen in combination, and the metal is brittle. To hinder the injurious effects of the oxygen, it is necessary to incorporate in the melted nickel some substance which has a strong affinity for oxygen, and also for the nickel itself. According to the *Comptes Rendus*, M. Garnier finds that phosphorus serves both of these purposes very satisfactorily, producing effects analogous to those of carbon in iron. If the phosphorus does not exceed .003 per cent., the nickel is soft and very malleable; above this quantity, the hardness increases at the expense of the malleability. Phosphorized nickel, when alloyed with copper, zinc, or iron, gives results which are far superior to those that are obtained from the same nickel when not phosphorized. By means of the phosphorus, Garnier has been able to alloy nickel and iron in all proportions, and always to obtain soft and malleable products.

Nickel-plating zinc.—According to a process for nickel-plating zinc, described in the *Journal of the Society of Chemical Industry*, the zinc is cleaned by dilute hydrochloric acid and thoroughly washed. It is then hung in the nickel bath for a short time, and on taking out is rinsed and thoroughly scraped, so removing all that does not adhere firmly. This is repeated till the zinc is covered with a thin film of nickel, which can afterwards be made as thick as required. The suitable current strength is easily found. When the zinc is once thoroughly covered the current may be increased without any risk of peeling off.

Nickel crucibles.—Nickel crucibles, instead of silver ones, are recommended by M. Mermet for use in chemical manipulations. Nickel, indeed, is slightly attacked by melted potash, but so is silver itself. Nickel crucibles cost at first much less than those made of silver, and moreover they have the great advantage of melting at a higher temperature. It often happens that inexperienced chemists melt their silver crucibles in heating them over a gas lamp; but such an accident is not to be feared in working with crucibles made of nickel.

Nickel in kitchen utensils.—It is well known that acids have a more or less decided solvent action on nickel, and on nickel-plating; and inasmuch as the use of nickel-plated kitchen utensils (in Germany) is becoming quite general, it is a matter of serious moment to determine what would be the effect on the human organism of the nickel which may find its way into the food prepared in such vessels. An investigation, having this purpose in view, has recently been made by F. Geerkens, who affirms that as much as one-half gram (about 7½ grains) of nickel may be taken into the stomach, and repeated for a long time, without producing any noticeably bad effects. When, now, it is considered that the quantity of nickel, which, by any probable means, could find its way into food in the course of its preparation in nickeled vessels, would be only a very fractional part of this quantity, there would seem to be no grounds for uneasiness in the use of nickeled kitchen utensils, especially where the same precautions are used as in the case of copper utensils, namely, thoroughly cleansing them and avoiding the storing of food in them.

Extraction of nickel from ores and scoriæ by electrolysis.—According to the London *Mining Journal* some improvements in treating ores or scoria containing copper or nickel, and in the apparatus to be used in the process, have been invented by M. Eugene Hermite; of Rouen, and are said to have been successful in practice. The ores or scoriæ are first subjected in the condition of fine powder, to the action of a solution of ammonia in the presence of compressed air, and subsequently subjecting the resulting liquid holding the metals in solution to electrolysis, preferably in apparatus constructed and arranged as hereinafter described. The ores or scoriæ containing the copper or nickel which it is desired to extract are first reduced to a fine powder and then placed in a vessel preferably so constructed as to be capable of rotating for the purpose of turning over its contents. A solution of ammonia is also introduced into the vessel, the proportion of ammonia in the solution being regulated according to the richness in metal of the ore or scoria, and the air in the vessel is then compressed to a pressure of from about three to four atmospheres. The vessel is then rotated for a length of time in accordance with the nature of the materials under treatment; from about thirty to sixty minutes will, he believes, be found to be the usual time required. After settling, the liquid holding the metal in solution is decanted; the ore is then washed again with a fresh supply of ammonia solution if required, and finally with water, but always under pressure. The liquid or solution obtained is afterwards subjected to electrolysis in vessels containing plates or electrodes of cast iron and carbon, the whole of the metal in the solution being collected on the cast-iron electrodes. A small quantity of caustic soda or potash may be added to the liquid in order to render it a better conductor. If preferred, the apparatus employed for the purpose of this invention may be made entirely of iron, as ammoniates of copper or nickel are not decomposed by this metal.

The operation of electrolysis is preferably performed in apparatus specially constructed and arranged, which is provided with a series of vessels in which the process of electrolysis is conducted. These vessels are preferably constructed of sheet iron with sealed or luted lids or covers having hydraulic joints, and contain cast-iron plates or electrodes arranged alternately with carbon plates or electrodes, each set of electrodes being connected to suitable conductors. The vessels communicate at the lower part through pipes or passages and valves with an outlet tube or passage for removing the separated metals that fall to the bottom of the vessels and the liquid. The liquid may be supplied to the vessels from a task or reservoir provided with a distribution pipe and delivery cocks. A traveling crane is preferably employed for lifting the covers and the electrodes and valves. The conductors are connected together by sleeves or unions, and are insulated from the sides of the vessels by insulators of porcelain or other suitable material. The vessels are charged with a liquid or solution obtained by treating ores as described, and the covers being secured in position a current of electricity is caused to pass through the solution. The metal is thereby separated from the solution and deposited on iron plates. When the operation is concluded, the metal is collected from off the plates or electrodes, and the liquid is drained off by opening the valves. The metal thus obtained may be melted and run into ingots, and the liquid may be used again if desired for treating a fresh supply of ore. Thus the essence of the invention is the treating ores or scoriæ containing copper or nickel with a solution of ammonia in the presence of compressed air and by electrolysis, and as a step in the treatment subjecting the same to the action of a solution of ammonia in the presence of compressed air.

IMPORTS AND EXPORTS.

The following tables show the amounts of nickel and nickel alloys imported, and the values of manufactured nickel, nickel coin, and nickel ore exported from the United States:

Nickel imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Nickel.		Oxide and alloy of nickel with copper.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1868	....	$118,058	....	....	$118,058
1869	....	134,327	....	....	134,327
1870	....	99,111	....	....	99,111
1871	17,701	48,133	4,438	$3,911	52,044
1872	26,140	27,144	....	....	27,144
1873	2,842	4,717	....	....	4,717
1874	3,172	5,883	....	....	5,883
1875	1,255	3,157	12	36	3,193
1876	....	....	156	10	10
1877	5,978	9,522	716	824	10,346
1878	7,486	8,837	8,518	7,847	16,684
1879	10,496	7,829	8,314	5,570	13,399
1880	38,276	25,758	61,869	40,311	66,069
1881	17,933	14,503	135,744	107,627	122,130
1882	22,906	17,924	177,822	125,736	143,660
1883	19,015	13,098	161,159	119,386	132,484
1884	....	....	194,711	129,733	129,733

Value of exports of nickel and nickel ore of domestic production from the United States.

Fiscal years ending June 30—	Manufactured nickel.	Nickel coin.	Nickel ore.
1864	....	....	$25,494
1865	....	....	36,710
1869	....	....	11,350
1872	....	....	43,500
1873	$19,780	....	19,891
1874	16,062	....	75,696
1875	26,000	....	72,020
1876	168,050	....	35,100
1877	8,200	....	....
1878	....	....	2,452
1880	4,120	....	....
1881	6,600	$32,880	....
1882	12,474	7,200	....
1883	9,911	....	12,182
1884	....	....	*a* 22,249

a Classed as "nickel and cobalt ore."

COBALT.

BY DAVID T. DAY.

Sources.—The oldest source of cobalt in the United States is the Chatham cobalt mine in Middlesex county, Connecticut. Here cobalt is found in the form of the mineral smaltite or speiss cobalt, an arsenide of cobalt, nickel, and iron, in varying proportions, the cobalt sometimes constituting 14 per cent. of the mineral. This mine is of considerable historical interest in connection with both cobalt and nickel (see "Mineral Resources of the United States, 1882," p. 401), but has not furnished any cobalt for many years. At the Mineral Hill copper mines, at the Patapsco mines near Finksburg, and at the Liberty mines near Sykesville, all in Carroll county, Maryland, the mineral linnæite, or cobalt pyrites, occurs. Niccolite containing small amounts of cobalt is also found there, but neither in sufficient quantity to justify mining. A vein of cobalt-bearing minerals in which smaltite is predominant has recently been discovered near Gothic, Gunnison county, Colorado. This property, owned by the Sterling Mining Company, has as yet received little attention, but sufficient to lead to the belief that it may become a commercial source of cobalt. The vein contains much crystallized calcite, in which smaltite and erythrite are irregularly distributed. It is particularly free from siliceous matter, and up to the present no nickel minerals have been detected in it. A sample of smaltite obtained from the surface croppings, analyzed by Dr. M. W. Iles, yielded the following results:

Analysis of smaltite from Colorado.

	Per cent.
Cobalt	11. 59
Iron	15. 99
Arsenic	63. 82
Silica	2. 60
Lead	2. 05
Sulphur	1. 55
Bismuth	1. 13
Copper	. 16
Nickel	Trace.
Silver	Trace.
	98. 89

A purer sample yielded 15 per cent. cobalt. The Gem and other mines near Silver Cliff, Colorado, contain a number of nickel minerals and a small amount of cobalt. Traces of cobalt have been found at Granite, Colorado, like that at Anthony's Nose on the Hudson river, in iron pyrites. Cobalt minerals have recently been found associated with niccolite in Grant county, New Mexico, in Bullard's Peak district, Burro mountains. Cobalt and nickel have also been discovered in the East Humboldt mountains, Nevada, not far from Lovelock's station on the Central Pacific railroad. Mr. Lovelock is the principal owner of the mountain in which the ore is found. It occurs in an 8-foot ledge between iron ore and gypsum, which is being opened by an incline. Fifteen tons of ore, sampled in San Francisco, are said to have yielded 12 per cent. nickel and 7 per cent. cobalt in the form of arsenide or smaltite. Six mines have been opened.

According to a paper read by A. D. Hodges, jr., at the February meeting of the American Institute of Mining Engineers, 1885, cobalt has been found with nickel at Ludwig & Carter's copper mine, near Mason's valley, Esmeralda county, Nevada, in a new mineral, which is usually black and massive, but sometimes consists of shining crystals. The proportion of nickel and cobalt is not constant, as will be seen from the following analyses of several specimens:

Analyses of cobalt ore from Esmeralda county, Nevada.

	No. 2.		No. 6.	No. 8.	No. 10.	No. 15.		
	1.	2.				1.	2.	3.
Water	15.98	16.0	Undet.	Undet.	Undet.	20.86	20.86	....
Silica	39.33	39.4	27.8	34.6	44.4	38.96	38.82	40.02
Alumina and iron peroxide (*a*)	25.79	30.2	30.4	17.0	12.0	4.29	4.15	3.95
Copper oxide	3.92	6.25	13.7	5.95	2.0	30.61	30.61	31.52
Manganese peroxide	3.93	2.7	10.4	10.0	9.9	Trace.	.68	....
Cobalt oxide	} [b]9.46	8.6	4.3	16.8	8.8	{ .49	.43	....
Nickel oxide						{ 3.59	3.47	....
Lime	1.02	Undet.	Undet.	Undet.	Undet.	Undet.	1.06	....
Magnesia	.57	Undet.	Undet.	Undet.	Undet.	Undet.	.04	....
	100.00	103.15	86.6	84.35	77.1	98.80	100.12	....

[a] Only a very little Fe_2O_3.
[b] By loss. Lost by breakage. Evidently contained much cobalt oxide.

It is not known to what extent the quantity of the mineral will justify mining.

At Mine la Motte, Madison county, Missouri, cobalt is found in the form of nearly all the cobalt minerals known. The principal ones are linnæite, smaltite, cobaltite, and asbolite or wad, the last being a mixture of the black and brown oxides of manganese, in which part of the manganese is replaced by cobalt. As distinct minerals these compounds of cobalt are only found at considerable depth, and the most valuable ore is galena, which when dressed contains only 0.2 to 0.3 per cent. of nickel and cobalt together. When much copper pyrites is found in the gangue the amount of nickel and cobalt may reach 1 to 1.5 per cent. Next in importance is the "middle product" of the dressing works, consisting of the sulphides of iron and copper with gangue and galena. This usually carries 20 to 23 per cent. of lead, 0.5 to 1 per cent. of copper, and 2.5 to 3.5 per cent. of nickel and cobalt. A large percentage of copper always coincides with an increase of nickel and cobalt. In some few cases 12 to 15 per cent. of copper gives 6.5 to 8 per cent. of these metals.

The mineral asbolite is also found near Albertis, Lehigh county, Pennsylvania, and opposite Fairmount (Philadelphia), in the same State.

The most important source of cobalt is the nickel mine at Lancaster Gap, Lancaster county, Pennsylvania. The ore consists of pyrrhotite (magnetic pyrites), in which a small part of the iron is replaced by nickel and a still smaller portion by cobalt. As mined this ore contains about 2 to 2.5 per cent. of nickel and the extremely small amount of 0.1 per cent. of cobalt. The fact that such a minute trace of cobalt can be extracted at a price low enough to compete with the product of richer foreign ores speaks creditably for the perfection of the process used at the American Nickel Works, at Camden, New Jersey, operated by Mr. Joseph Wharton, who owns and works the Lancaster Gap mine.

The question whether or not an ore of cobalt can be utilized on a commercial scale is determined at present, in this country, by the amount of nickel which it also contains. If there is enough nickel to pay for reducing the ore, it is worked up for the nickel and the cobalt is obtained as a secondary product. Cobalt is therefore a mere feature of the nickel industry; the amount produced and the price are ruled to a large extent by nickel. The reason for this is that cobalt alone is not found in this country in sufficient quantity to justify its utilization, even at a much higher price than it is worth now. Minerals comparatively rich in cobalt are found in several of the localities cited above, but although the price of cobalt would justify shipment of ores, if sufficiently rich, from remote districts, the amount of the ore is entirely too small to be profitable.

Production.—Until the year 1863 the presence of cobalt in the domestic ores of nickel was ignored, or at least there was no regular establishment where cobalt was separated from nickel. This separation was begun as a particular feature of the Camden nickel works when leased by Mr. Wharton. The following table gives the amounts of cobalt oxide obtained at the Camden works since 1869. As only trifling amounts of cobalt oxide have been made at Mine la Motte, and none in the last few years, this table represents practically all the cobalt oxide obtained in the United States. The amount made in 1868 and before that date was lost in a fire which destroyed the works:

Production of cobalt oxide in the United States.

Years.	Pounds.	Years.	Pounds.
1869	811	1878	4, 508
1870	3, 854	1879	4, 376
1871	5, 086	1880	7, 251
1872	5, 749	1881	8, 280
1873	5, 128	1882	11, 653
1874	4, 145	1883	1, 096
1875	3, 441	1884	2, 000
1876	5, 162		
1877	7, 328	Total	79, 868

The small amount of cobalt oxide made in 1883 and 1884 is accounted for by the fact that the Camden nickel works were not in operation from January, 1883, till August, 1884. There was an over supply of nickel. After this surplus had been exhausted operations were renewed. The amount of cobalt made is limited by the demand for nickel, and there is not enough made in this country to supply the demand. Cobalt oxide and some smalt are therefore imported. In former years ores of cobalt were also imported, probably in the roasted form called "zaffre."

A small amount of cobalt and nickel ores are mined in Great Britain. In 1882 the amount was 38 long tons, valued at $1,156; and in 1883 49 long tons of ore were mined, all from the Fod Hiraddag mine in Wales. In Prussia the one cobalt mine reported as working produced 66 metric tons of dressed ore in 1882 and 97 tons in 1883; the number of men employed was 69 in 1882 and 106 in 1883.

Imports.—The bulk of the imported cobalt oxide is manufactured in Germany. The amounts imported since 1868 are given below:

Cobalt oxide and ore imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Oxide. (*a*)		Ore. (*b*)		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1868		$7, 208			$7, 208
1869		2, 330			2, 330
1870		5, 019			5, 019
1871		2, 766			2, 766
1872		1, 920		$72	1, 992
1873	1, 480	4, 714	9, 769	920	5, 634
1874	1, 404	5, 500	3, 798	612	6, 112
1875	678	2, 604	5, 355	659	3, 263
1876	4, 440	11, 180	6, 968	962	12, 142
1877	19, 752	11, 056	18, 377	2, 390	13, 446
1878	2, 860	8, 693	20	1	8, 694
1879	7, 531	15, 208			15, 208
1880	9, 819	18, 457	2, 424	108	18, 565
1881	21, 844	13, 837			13, 837
1882	17, 758	12, 764	3, 102	367	13, 131
1883	13, 067	22, 323			22, 323
1884	25, 963	43, 611			43, 611

a Not enumerated until 1868. *b* Not enumerated until 1872.

The extraction of cobalt from the ores.—The method employed for extracting cobalt oxide from the ore varies according to the richness of the ore and the impurities with which it is mixed. In Germany ores rich in cobalt are found in small quantities but sufficient to work profitably for cobalt independent of nickel. Such rich arsenical ores were formerly simply roasted in the air, giving an arsenate of cobalt which found its way into the market as "zaffre." But as the cobalt ores frequently contain considerable amounts of nickel and iron, an additional step was necessary before a compound of cobalt could be produced of sufficient purity to give a good blue color to glass and fill the other requirements. The roasted ores are fused with carbonate of lime or some other flux, when the iron flows on the surface as a slag, leaving a heavy speiss of cobalt below. In this fusion the cobalt is partly oxidized, but the nickel remains for the greater part as sulphide. This speiss is then fused with a mixture of white sand and potash. The fusion is effected in large earthen pots, arranged in a furnace similar to that employed for the manufacture of plate glass. The arsenides of nickel, residual iron sulphide, and copper sulphide sink to the bottom of the pot, and the blue glassy substance on top, which contains the cobalt, is ladled out into water. This blue glass is called "smalt." It varies in composition according to the different quality of the cobalt ores used for its preparation, and also according to the amount of sand and potash with which it is fused. It is a silicate of cobalt and potassium in which the amount of silica varies between 56 and 70 per cent., that of potash between 12 and 22 per cent., and that of cobalt between 6 and 16 per cent. In addition smalt contains small quantities of alumina, ferric oxide, and frequently also lime and oxide of lead; the commoner kinds also contain oxide of nickel. As sent into the market it is in the form of a blue powder. Up to the middle of this century smalt was largely used for coloring starch and paper, but the recent introduction of artificial ultramarine has largely diminished the demand for cobalt blue. Smalt has the advantage as a paint over ultramarine in not being attacked by acids. (*a*)

When, as in the case of nickeliferous pyrrhotite, the amount of nickel and cobalt in the ore is extremely small, a third modification of the extraction process is used. The ore is enriched at the mines to a matte containing about 10 per cent. of nickel and cobalt; after thorough roasting this is dissolved in hydrochloric or sulphuric acid. If the solution now contains ferrous salts they are oxidixed by bleaching powder, and the iron is precipitated by the addition of lime or chalk, while copper is precipitated as sulphide. The cobalt is then precipitated as oxide, the nickel remaining in solution. By this means cobalt oxide is obtained; and this is the general form in which cobalt comes into the market at present, both by importation and from the works in this country.

At Mine la Motte no cobalt is made into the usual form of oxide, but the nickel and cobalt are worked into a matte which is shipped to Europe for further treatment. The following account of the process is taken from an article presented to the American Institute of Mining Engineers, February, 1885, by Mr. James M. O'Neil: On roasting and then smelting dressed galena, lead, "first matte," and slag are obtained. The nickel and cobalt, which formed from 0.2 to 0.3 per cent. of the galena, are now found in the "first matte" to the amount of 3 to 3.5 per cent (about 2 nickel to 1 cobalt). This is roasted and used as "iron flux" for smelting galena. By this process "second matte" is obtained with from 3.5 to 6.5 per cent. nickel and cobalt. Until recently this was roasted and smelted with acid fluxes, producing "third matte" with 12 to 17 per cent. nickel and cobalt, which was packed in barrels and shipped to Europe. Mr. O'Neil has found, however, that by melting the third matte with mispickel ores containing 23 per cent

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[a] Roscoe and Schorlemmer's Chemistry, vol. 2, part 2, page 133.

arsenic the nickel and cobalt form with the arsenic a clean speiss carrying 36 per cent. nickel and cobalt. This experiment, though not financially successful, proved satisfactorily that arsenic would separate the nickel and cobalt from the lead and would prevent large losses in the slag. Subsequent experiments with second matte have proved that the old method must be abandoned, certainly for the treatment of the second matte; whether it will not be more economical to treat the first matte also with speiss remains to be determined.

Value.—Metallic cobalt has a nominal value of $14 per pound. Cobalt oxide has varied between $2.50 and $3 per pound during the last twenty years, except at one period, when it rose markedly. It has never been as low as $2. The recent agitation concerning the supposed curative properties of light transmitted through blue glass exerted a marked influence on the price of cobalt oxide, with which such glass is colored. The price went as high as $6 per pound in the hands of dealers, although this figure was never the manufacturers' price. This extraordinary price continued as long as the agitation, for a shipment from England to supply the increased demand was lost at sea. During 1883 and 1884 the average price of cobalt oxide was $2.55 per pound, making the value of the product of 1883 $2,795 and for 1884 $5,100. The price of smalt varies from 8 to 15 cents per pound.

Utilization.—Metallic cobalt has never been used except experimentally. Some years ago Mr. Joseph Wharton prepared a quantity of metallic cobalt in order to test its application as a substitute for nickel in plating. He plated half of certain pieces of iron with nickel and half with cobalt and exposed the pieces to oxidizing processes. This experiment, repeated in various forms, showed that cobalt oxidized somewhat more easily than nickel, and was therefore not quite as useful for plating. It has no advantages over nickel and is more costly, and the attempt to utilize it was abandoned. The one use for cobalt in the arts is for the blue color it gives in certain combinations. The oxide is usually the starting point in making the blue colors. It is added to glass to produce ordinary blue glass; it is also used in correcting the yellow color in pottery. Smalt is also used for both these purposes and particularly for furnishing a light blue body to pottery by mixing with clay and avoiding too high a temperature in baking, by which a dark blue would be produced. Cobalt oxide is much used for all kinds of decorative work on pottery. It is a valuable "underglaze" color, as it is not injured by a high temperature. Cobalt salts were formerly used for coloring paper and for blue ruling, but now ultramarine has been substituted. Rinnman's green is also a compound containing cobalt, which has lately been improved in quality for use in the arts. Thénard's blue, or cobalt ultramarine, is a fine blue compound obtained on the large scale by heating a mixture of alumina and phosphate or arsenate of cobalt. Recently an alloy containing a small amount of cobalt has been made at Birmingham, England, under the name of "cobalt bronze."

MANGANESE.

By David T. Day.

Occurrence.—Manganese occurs as an essential constituent of several well known minerals, and it is also found in small quantity in many others, often giving them a characteristic color. Silicates frequently contain traces of manganese, and by their decomposition manganese passes into the soil and is taken up to a slight extent by plants. Further it may be stated as a general rule that where iron ores occur the ores of the closely allied metal manganese may also be found, sometimes in well defined masses, more frequently forming merely a small percentage of the iron ore. On the other hand all the manganese minerals are found to contain iron, though occasionally large beds of manganese ores are met with in such pure condition that iron can be found only as a trifling impurity, less in amount than that of other metals such as nickel and cobalt. The question whether a given mineral can be considered a practical ore of manganese is decided not merely by the amount of metallic manganese which it contains, but principally by the use to which it is put. It thus frequently happens that ores very poor in manganese find sale, while others containing three or four times the amount remain unmined. The two principal uses for manganese are (1) in the form of manganese dioxide as an oxidizing agent, and (2) as an addition to iron. For the first the richest ores obtainable are the only ones used. But frequently an ore containing only a small amount of manganese but comparatively rich in iron is used as a valuable source from which to obtain iron alloyed with the desired amount of manganese. It is to be borne in mind that in this last use—as an addition to iron—the richer ores would be valuable if it were not for the fact that they usually contain phosphorus in some form of combination.

Character of the ores.—Manganese is chiefly found as manganese dioxide or pyrolusite (MnO_2); it also occurs as braunite or brown oxide of manganese (Mn_2O_3); manganite (Mn_2O_3, H_2O); hausmannite (Mn_3O_4); and as psilomelane, which contains manganese dioxide together with compounds of barium or potassium and frequently iron, nickel, or cobalt. Manganese carbonate also occurs in quantity sufficient for its use as a valuable ore in Germany; and knebelite and manganiferous garnet, both silicates containing iron and manganese, have found special application in the manufacture of spiegel iron. Pyrolusite and braunite have been the important manganese ores of the United States until recently, when a hydrated variety of psilomelane called "wad" or "bog manganese" has become an article of commerce. The terms used by dealers to distinguish the various ores of manganese are frequently different from those given here, and much confusion exists. For a discussion of this subject the reader is referred to "Mineral Resources of the United States, 1882," page 425.

Localities in the United States.—The extent of the manganese deposits in the United States is unusually great when compared with the deposits in other lands. They occur irregularly distributed through the eastern States from Maine to Georgia. Mines were formerly worked for bog manganese in several well known localities in Knox, Oxford, and Hancock counties, Maine. Bog manganese is again met with, though sparingly, in New Hampshire, Vermont, Massachusetts, Rhode Island, New York, and Pennsylvania. From Maryland to Georgia black oxide of manganese is much more common than bog manganese, although the latter is met with occasionally in Virginia and North Carolina. These deposits of black oxide are the important sources of American manganese. The most northern deposit is near Brookeville, Montgomery county, Maryland. This was formerly worked, but no manganese ore is now mined in Maryland.

Proceeding southward, the Crimora mine at Crimora station on the Shenandoah Valley railroad, Augusta county, Virginia, ranks as the most important mine in the United States. In 1867 a stock company bought the land containing this mine from Mr. Flannigan, of Charlottesville, for $3,000; as soon as operations for mining were actually begun, the mine was valued at $24,000. The stock company continued mining until 1869, when the total receipts showed a loss, owing to lack of experience in the managers. From May, 1869, to April, 1882, the mines were alternately either idle or worked by Mr. Samuel W. Donald in the interest of the stock company. On April 29, 1882, the mines were leased for five years to Messrs. James B. White & Co., of Pittsburgh, Pennsylvania, who have put in new machinery and increased the yearly product about fourfold. During the early years the ore was shipped to England and Belgium; lately it has been used in making spiegel iron in this country and for making bromine on the Ohio river. An analysis of the Crimora ore, made by Prof. Andrew S. McCreath, is given below. The analysis was apparently made from a particularly good specimen and cannot be said to represent the average value of the ore. It serves however to indicate the nature of the impurities met with in manganese ores.

Analysis of pyrolusite from the Crimora mine, Virginia.

	Per cent.
Manganese dioxide	81.70
Manganese oxide	7.28
Ferric oxide	.55
Cobalt oxide	.35
Nickel oxide	.09
Zinc oxide	.62
Alumina	.90
Baryta	.83
Lime	.88
Magnesia	.63
Phosphoric acid	.17
Alkalies	.47
Silica	2.13
Water	3.40
	100.00

Manganese is found at as many as thirteen other points in Wythe, Giles, Bland, Campbell, Louisa, Nelson, and other counties of Virginia. The mines in Pittsylvania and Nelson counties are especially large. At Goshen Bridge, Rockbridge county, mines have been opened from which 20 tons per day can be furnished.

In North Carolina manganese ores (pyrolusite and wad) are met with in Cherokee, Catawba, and Cabarrus counties, but not in large quantity and of a hard quality. As a rule these hard ores are coincident with poor ores, because pyrolusite is softer than the less valuable manganite and braunite. In South Carolina deposits have been found at Hard Labor creek, and a project is on foot to obtain manganese from the Dorris mine.

The chief rivals of the Virginia ores are those of the "Etowah region," Bartow county, Georgia. A Virginian named Ruckman discovered manganese at Cass station, Bartow county, and recognized a similarity between these ores and those of Virginia. In 1867 the property was bought for mining purposes by Mr. M. G. Dobbins, who has furnished the following information: In 1870 the mines were rented to a company of New York capitalists who extracted about 5,000 tons of ore from less than one-half acre of land, without going deeper than 40 feet. The property has now gone into the hands of the Bartow Manganese and Manufacturing Company, with $30,000 paid stock. The company consists of M. G. Dobbins and others. Nearly the whole year has been spent in placing machinery in position and in other preparations for work. The indications are that the ore will find sale in Pittsburgh. A small quantity has been shipped to England. The following analyses give a fair idea of the average character of the ore. No. 1 is a sample analyzed in New York; No. 2 is taken from a lot of ore shipped to England.

Analyses of pyrolusite from the Etowah region, Georgia.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Manganese oxide	80.00	80.58
Iron peroxide	.54	15.72
Graphite	....	1.34
Silica	.60	1.32
Alumina	.13	....
Lime	.90	....
Magnesia	.15	....
Sulphur	.027	....
Phosphoric acid	.33	....
Water and carbonic acid	17.00	1.15
	99.677	100.11
Manganese available for chlorine	....	65.35

At Woodstock station, Calhoun county, Alabama, about 2,000 tons of manganiferous ore, containing 36 per cent. metallic iron and 23 per cent. manganese, were mined for the Woodstock Iron Company, of

Anniston, Alabama, for making spiegel iron. The production has ceased; no ore was mined in 1883 or 1884. The deposits at Candutchkee, Clay county, have never been mined. In Dixon county, Tennessee, there are more extensive deposits, but not rich enough to be used for the manganese alone.

Recently an effort has been made to obtain manganese from the deposits known to exist in Arkansas. The following history of these deposits is due to Mr. A. M. Evans, general superintendent of the White River Mining Company: The discovery of manganese ore in Arkansas was accidental. About thirty years ago a Colonel Martin, of Tennessee, bought lands in Independence county, and finding pieces of manganese ore, had them analyzed, and called the attention of the iron masters in England to the discovery. The civil war put a stop to further operations. The deposits lay untouched until three years ago, when Mr. E. H. Woodward began working them, and now several companies are engaged in the enterprise. The ore, which is black oxide of manganese, occures in "pockets" in an ellipitical belt of land, the major axis of which extends for 15 miles through Independence and Izard counties, beginning 3 miles from Batesville. Its minor axis is from 6 to 8 miles long. The ore is found resting upon Silurian limestone. Much of it is on the surface, and the cost of mining is said to be very small. The following are analyses, the first of a picked sample, the other three samples of carloads:

Analyses of manganese ore from Arkansas.

	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Metallic manganese	62.00	49.06	52.26	55.02
Metallic iron	1.05	3.04	3.52	2.05
Silica	1.00	4.00	2.11	2.00
Phosphorus	.01	.12	.098	.15

Up to the present little has been done in sending the ore to market, but after an era of prospecting, several companies have been organized and mining operations have actually begun. It is probable that not more than 5,000 tons have ever been mined from these deposits. The Ferromanganese Company, of which Mr. E. H. Woodward is president, has mines about 12 miles from Batesville; it employs some twenty men, with eight or ten teams, and has shipped about 50 tons of ore. The Arkansas Manganese Mining Company, composed principally of Messrs. W. C. Whitthorne, John C. Brown, and Jerome Hill, all of Tennessee, has made some shipments of ore to Saint Louis, and is preparing for extensive operations. Mr. A. M. Evans represents a corporation known as the White River Mining Company. This company has shipped about 200 tons of ore. The White River Mining and Transportation Company controls a very large body of manganese lands, and has commenced operations. Besides the companies named, the firm of Hunton & Gibb, of Batesville, is making preparations for active work. The industry is in the experimental stage, and many questions remain for decision by practical tests before the true importance of the new field can be determined.

There are many deposits in Virginia which once gave promise of great value but, for one or another slight objection, are not mined. Aside from the usual considerations of the percentage of manganese, amount of ore, cost of getting it out of the ground, freight to a manufacturing center, etc., is the one of whether the possible impurities will prevent it's use in the manufacture of steel. For the other uses of manganese the supply from the eastern States fully equals the demand. But the attempt to use some of these eastern ores in steel making has not been markedly successful so far, because of the phosphorus which the ores contain. A small amount of this substance in steel renders it "cold short," that is, brittle when cold, and more than counteracts the beneficial effect of the manganese. Heretofore Spanish iron ore, containing small amounts of manganese and remarkably free from phosphorus, has been used for steel. The analyses given of the Arkansas ore indicate that it may not contain too much phosphorus to act as a valuable substitute for the imported ore. If this proves to be true it is probable that Arkansas will exert a powerful influence on the whole industry, whether the ore can be brought to market as cheaply as the Virginia ore or not. It is evident from the amount of capital invested that the necessary tests will soon be made.

Manganese minerals are again met with on the Pacific slope. The following information has been furnished by Mr. C. G. Yale: Manganese is found in heavy deposits in California and Nevada and occurs in greater or less quantity in the Rocky Mountain region. The only deposit that has been worked to any extent is on Red Rock island in the bay of San Francisco, concerning which nothing further is to be said than was given in "Mineral Resources of the United States, 1882," no ore having since been mined from this or any other manganese deposit on the Pacific coast. The following comprise the other localities in California where the mineral has been observed: Near Angel's Camp and at Railroad Flat, Calaveras county; abundantly at Corral Hollow, Contra Costa county; near Saucelito and Tomales, Marin county; Sweetland, Nevada county; Mount Saint Helena, Napa county; at Argentine and Mumford Hill, Plumas county; near Colton, San Bernardino county; Bernal Heights, near the city of San Francisco; at several places in Santa Clara and Sonoma counties; and near the town of Columbia, Tuolumne county, where pieces of ore weighing 100 pounds or more have been picked up on the surface of the ground.

Foreign sources.—The manganese ore occurring in Nova Scotia has an important bearing on American industries on account of its exceptional freedom from iron, which makes it valuable for neutralizing the green tint imparted to glass by iron. According to an article by Mr. Edwin Gilpin, read before the Royal Society at the Ottawa meeting, this pure pyrolusite is found in Hants, Colchester, Pictou, and Cape Breton counties, in quantities sufficient for profitable mining. Some of these ores are said to contain 95 per cent. manganese dioxide and mere traces of iron. Small amounts are regularly imported by glass manufacturers at prices quite out of proportion to native ores.

In Germany, Sweden, and Russia local deposits are used by iron manufacturers, but when particularly pure ores are desired all these countries import from the rich deposits in Spain and Portugal. Carthagena, Huelva, Marbella, and Bilboa are the principal shipping ports, and England particularly obtains large amounts of ore from these points.

Production.—The statistics from many of the small mines of Virginia and North Carolina are practically inaccessible. It is therefore impossible to determine exactly the total quantity mined, but the amount for 1883 and 1884 can be stated as 18,000 long tons to a very close approximation, of which 8,000 tons were mined in 1883 and 10,000 in 1884. Of this amount Virginia furnished fully three-fourths, Arkansas a fifth, and the balance was contributed by Georgia and North Carolina. In former years Virginia furnished nearly all the manganese mined in this country. The following table gives the actual number of tons obtained from the Crimora mine, which furnishes by far the largest part of the Virginia supply:

Production of the Crimora mine, Virginia.

	Quantity.
	Long tons.
Prior to 1869	5,684
May, 1869, to February, 1876	280
February, 1876, to December, 1878	2,326
December, 1878, to December, 1879	1,602
December, 1879, to December, 1880	2,353
December, 1880, to December, 1881	2,327
December, 1881, to April, 1882	165
April, 1882, to December, 1883	4,841
December, 1883, to November 19, 1884	8,473
Total	28,051

The production of manganese ores in foreign countries has always been much greater than in the United States. In 1874, the production in Germany was given as 18,725 long tons; in Austria, 4,937 long tons; the Huelva district, in Spain, 48,207 long tons; in England, 6,552 long tons. In the latter country the production has diminished markedly; thus in 1882, 1,548 long tons, with a value of £3,907, were mined in Great Britain. In 1881, Portugal produced 9,906 long tons. The production in Italy for three years ending 1879, as furnished by American Consul-General Richmond, was:

Production of manganese ore in Portugal.

Years.	Long tons.	Value.
1877	6,812	$40,597
1878	6,655	48,256
1879	5,705	35,065

Value.—During the year 1883 the price of black oxide of manganese in the United States ranged from $11 to $16 per ton, according to the percentage of manganese. The total value of the year's production was about $120,000. The price declined in 1884, and manganese ore containing 75 per cent. manganese dioxide is now worth $12 per ton at the mines, or 27 cents per metallic unit delivered at Pittsburgh or Johnstown. The total product of 1884 may also be valued at $120,000. The cost of mining varies from $5 to $10 per ton in the eastern States. It is claimed that the Arkansas deposits which occur near the surface can be mined for $1.25 per ton.

Imports.—Manganese ores are imported from Nova Scotia, as already mentioned, for use in the manufacture of glass. Some manganese also finds its way into this country in the form of iron ore containing about 20 per cent. manganese. It is brought from Carthagena and Marbella as ballast by vessels seeking cargo. The importations from 1869 to 1884, inclusive, are given in the following table:

Oxide and ore of manganese imported and entered for consumption in the United States, 1869 *to* 1884 *inclusive,*

Fiscal years ending June 30—	Quantity.	Value.
	Pounds.	
1869	....	$11,864
1870	....	10,685
1871	....	12,321
1872	....	9,768
1873	1,226,157	12,466
1874	1,507,448	16,992
1875	1,119,893	16,300
1876	386,408	5,805
1877	1,326,136	15,747
1878	3,068,634	31,571
1879	554,372	12,094
1880	1,864,968	19,825
1881	1,283,457	20,432
1882	2,225,936	38,879
1883	1,425,274	28,952
1884	1,151,531	24,326

The imports in 1884 were classified as—

	Pounds.	Value.
Ore	1,000,095	$19,989
Oxide	151,436	4,337
Total	1,151,531	24,326

Exports.—England has been a consumer of American manganese ore since its mining was first commenced. The ore is used in the manufacture of chlorine. The following is the value of the exported ore from 1869, which was practically the beginning of manganese mining in this country, to the present time:

Value of manganese ore exported from the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$43, 382	1875	$2, 261
1870	56, 125	1876	1, 030
1871	7, 760	1878	3, 569
1873	41, 075	1883	6, 165
1874	9, 939	1884	1, 802

Utilization.—The uses for manganese ores may be grouped under two heads: (1) those in which the oxygen combined with the manganese is used, and (2) those in which manganese itself is sought. For the first group only ores which are rich in manganese dioxide are used. When heated strongly or treated with powerful acids, this substance serves as a convenient source of pure oxygen. More frequently it is used as an "oxidizing agent," that is, to give up oxygen to some other substance, rather than to furnish oxygen in the elementary form. Thus chlorine and bromine are prepared by this oxidizing action of manganese dioxide in the following way: It is extremely difficult to separate these elements from others with which they are ordinarily in combination; it is comparatively easy, however, to obtain the compound of chlorine known as hydrochloric or "muriatic" acid from ordinary salt by treatment with sulphuric acid. When this substance is warmed with manganese dioxide, oxygen from the latter combines with the hydrogen of the acid, leaving part of the chlorine free. Large amounts of manganese are used annually for this purpose, in England particularly. The manganese is converted by this process into manganese chloride, which serves as a convenient substance from which all the other salts of manganese can be made. A brown and a black pigment can be obtained indirectly from it by heating it in contact with air. A green pigment is made by heating manganese carbonate, obtained from the chloride, in closed vessels. The beautiful violet color which manganese gives when fused with phosphoric acid salts led to the manufacture of a violet pigment called manganese or Nurnberg violet, from these same chlorine residues. "Rosenstiehl's green," obtained from this source, is used somewhat for printing on paper. It has been found that certain of the salts corresponding to manganese chloride hasten the oxidation of linseed oil. Thus when linseed oil is boiled with manganese dioxide, the addition of manganese borate aids in the desired oxidation. The most important use of these waste residues from the chlorine manufacture is in preparing potassium and sodium permanganates. Formerly native manganese dioxide was fused with potassium chlorate and potassium hydroxide, but the finely pulverized oxide obtained from manganese chloride is easier to convert into permanganates. This permanganate of potassium is used not only for purely chemical purposes, such as the preparation of specimens and the oxidation of various substances in analytic chemistry, but also for technical purposes in determining the value of iron ores, in bleaching leather and textile fabrics, for the preparation of oxygen according to Motay's process, and for sanitary purposes as a powerful disinfectant. But these uses do not consume all the manganese chloride which continually results from the manufacture of chlorine. It is customary, therefore, to reconvert manganese chloride by Weldon's process into a substance capable of oxidizing hydrochloric acid. By this means the same manganese is used repeatedly. Were it not for this, the demand for manganese ores would probably be more than doubled. Bromine is made in a similar way, and about one-fifth of the manganese ore mined in the United States is used at Pomeroy and other places on the Ohio river, in the West Virginia and Ohio salt district, for making bromine. Thus far no attempt has been made to regenerate the manganese so used in America. Until recently nearly all the native ore was used for one or another oxidizing purpose in this country, or shipped, for similar use, to England. Meanwhile large amounts of manganese were imported to furnish manganese to the Bessemer steel works. There has been prejudice against American ores on account of the phosphorus they contain. Within the last few years, however, the manufacture of steel has consumed the greater part of the native ore. In just what way manganese proves advantageous in making steel has been an interesting subject of discussion, but one in which it is extremely difficult to obtain facts; partly because steel manufacturers are not ready to reveal the secrets of their industry, and also because there are great differences in the views held by authorities. The following will serve to indicate at least the main features of this subject; further information will be found in the treatises on metallurgy by Percy, and in "Steel, its History, Manufacture, and Uses," by J. S. Jeans, from which much of what follows has been taken:

It was known in quite early times that certain iron ores furnished pig iron from which particularly good steel could be made; it was shown, later, that this ore contained oxides of manganese, but it was barely suspected that it was the manganese which gave the improved character to steel, until, in 1839, Josiah M. Heath found as the result of many experiments that when a small amount of manganese is introduced into steel of poor quality in the melting pot, the steel is uniformly improved and can be welded to iron with facility. The enormous change which this discovery effected in the English manufacture of steel is sufficient testimony to the correctness of Heath's claim that the quality of poor steel is improved by the addition of small amounts of metallic manganese. It became possible by its aid to dispense with Russian and Swedish iron and use the inferior English iron. The use of manganese became general, and it has been calculated that a saving in the cost of steel amounting in all to $10,000,000 had been effected by 1855. When the Bessemer process of making steel was introduced it was found that the finished metal contained as much phosphorus as the pig iron from which it had been made. It was "cold short," and the effort was made to add some substance which would overcome this objection either by removing the phosphorus or by counteracting its effects. For several years Bessemer was unable to do this, and was obliged to use pure Swedish pig iron in his process. In 1856 Robert Mushet added to the iron made in a Bessemer converter a small quantity of cast iron containing manganese, and found that good steel could thus be made from very impure cast iron. He recommends adding from 1 to 5 per cent. manganese to the metal, according to the degree of hardness desired in the resulting steel. This process immediately became a general one, and now a certain amount of pig iron containing manganese is always introduced just before Bessemer steel is finished. In the manufacture of open-hearth steel also, manganese is used, so that at present manganese in the form of an alloy with iron is always added to Bessemer and open-hearth steels before these are finished. But as to the exact function of manganese many opinions have been expressed. Both Heath and Mushet proposed to add nearly 3 per cent. of manganese, but usually steel is found to contain less than 1 per cent.; it is therefore evident that the larger part finds its way out of the iron again, and if it produces any beneficial effect this must be sought in some reaction which it aids during its removal, by which the steel loses some impurity. It has been shown that sulphur can be removed to a considerable extent when manganese is introduced into a Bessemer converter. The majority of metallurgists believe, however, that the great benefit is due to the removal of oxygen from the finished steel. It is impossible to distribute the air of the blast perfectly through the molten metal, and hence some oxide of iron will be formed in one portion of the steel before all the carbon has been removed from another; the manganese introduced will oxidize more readily than iron, and will reduce any oxide of iron that is formed. The oxide of manganese is either blown out of the converter in a flocculent mass or unites with the slag, and thus leaves the steel in a more homogeneous condition. The amount of phosphorus in steel is not changed by the addition of manganese, but it seems that its deleterious effect is not so apparent when a small amount of manganese is present. According to Mushet nothing is gained by adding manganese to steel which contains no impurities. The present opinion seems, therefore, to be that manganese is valuable (1) in deoxidizing steel, (2) in aiding the removal of sulphur, and (3) in counteracting the effect of phosphorus. The best form in which to introduce manganese into steel would undoubtedly be that of the pure metal; but manganese is so difficultly fusible and oxidizes so readily that it is impracticable to reduce it from its ores; pure manganese, therefore, is never used. It is much easier to reduce a mixture of the oxides of manganese and iron and thus obtain an alloy of these metals, which is usually called "spiegel iron" when the manganese is less than 15 or 20 per cent., and "ferromanganese" when it exceeds this percentage, though in practice the terms are sometimes used indiscriminately.

Manufacture of spiegel iron is carried on largely in Germany, France, and England, and lately has become a feature of American steel works. The following account of its manufacture is taken by Jeans from an article by Forbes in the *Journal of the British Iron and Steel Institute:* The ores used for making spiegel iron vary in the different countries. In Germany it is made entirely from manganiferous spathic carbonate of iron; in Russia it is reduced from ferruginous oxides of manganese; and in Sweden it is produced by smelting a mixture of knebelite and manganiferous garnet, both of which minerals are compound silicates of iron and manganese. In one point, however, the methods all agree; namely, that in all these ores the oxides of manganese and iron, if not in actual combination as compound silicates or carbonates, are at any rate in a very intimate admixture with one another, and therein lies one of the most important features connected with this manufacture. Until the year 1872, wherever true ores of manganese had been added to the usual charge of a blast furnace with the expectation of obtaining spiegel iron rich in manganese, it was found as a general rule that only a small fraction of the manganese combined with the iron, the major part being carried off in the slag. For this reason, when it was desired to produce a cast iron containing much manganese it was deemed requisite that this metal should be added to the charge in the shape of some strongly ferruginous compound, thereby facilitating the process of reduction, since a mixture of the two oxides (of manganese and iron) is much more easily reduced to the metallic state, and so enabled to unite with the iron, from the rest of the charge, than oxide of manganese alone, which, unless the heat is very intense and the reducing action of the furnace nearly perfect, is extremely apt to go into the slag in the state of silicate, from which it can subsequently be recovered only with great difficulty. The oxides of manganese are very much less easily reduced and require more time as well as a much higher temperature than the oxides of iron, and hence it follows that in making spiegel iron particular attention should be paid to the following points:

1. The mineral used as a source of manganese should be in itself highly charged with iron, so as to facilitate and insure the reduction of as large an amount of the manganese contained in it as possible.

2. The charge of the furnace should be highly basic, or, in other words, an excess of limestone, or preferably burnt lime, should be used.

3. The working of the furnace should be much slower than is usual in iron smelting, in order to allow more time for the reduction of the oxides of manganese.

4. The temperature of the blast furnace should be as high as possible, using as hot a blast as can be obtained, and as coke admits of the use of a sharper blast, and affords greater heat, it is to be preferred to charcoal in this manufacture.

Russian spiegel iron is smelted with charcoal and is known for its good quality. In order to increase the amount of manganese in gray pig iron which already contains 1.2 per cent. of manganese, so as to obtain spiegel iron, 12 to 15 per cent. of pure native oxide of manganese (pyrolusite) has been added, producing a low spiegel iron containing from 5 to 6 per cent. metallic manganese.

In Sweden spiegel iron is made by smelting a mixture of knebelite and manganiferous garnet containing an average of 42 per cent. iron and 13 per cent. manganese with equal parts charcoal and coke, the ore being fluxed with 30 per cent. limestone. The ore frequently contains visible particles of galena, pyrites, and zincblende, but it is stated that no sulphur is found in the spiegel iron, although the slag, which has a peculiar yellow-green color when the furnace is working well is said to contain 4 per cent. sulphur, and up to as much as 16 per cent. oxide of manganese. The ordinary spiegel iron made at Schisshyttan, Dalecarlia, is superior to the average German product, and contains an average of 13 per cent. manganese, with about 4 per cent. carbon, or 5 per cent. carbon and silicon. Occasionally it has been as high as 17 per cent. Alexander Keiller, the manager of these works, informed Forbes that he was, in 1872, producing spiegel iron which averaged 15 per cent. manganese, with only 2.5 per cent. carbon, but that this metal was altogether different in appearance and could not be made to assume the crystallized, bladed, reflecting fracture peculiar to spiegel (specular) iron, and from which its name is derived. The characteristics of good spiegel iron are thus described: (1) A highly crystalline structure with large and smooth cleavage planes; (2) a tendency to iridescent tarnish, and (3) a chemical analysis showing 10 to 12 per cent. metallic manganese, which is quite sufficient for ordinary purposes, about 4 per cent. combined carbon, less than 1 per cent. silicon, not more than 1 per cent. phosphorus or copper, and only traces of sulphur and other elements. Uncombined carbon in the form of graphite should not be present.

The following analyses of spiegel iron represent the character of the best kinds imported into New York in 1868, 1869, and 1873:

Analyses of imported spiegel.

	1868.		1869.		1873.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Iron	85.57	84.455	84.122	84.869	....	....
Manganese	9.142	10.625	10.568	10.223	11.130	10.22
Copper	.032	.034	.036	.031	.279	.20
Nickel and cobalt	.005	.005	.004	.002	....	....
Silicon	.068	.368	.268	.384	....	....
Carbon	5.048	4.304	4.907	4.461	....	....
Sulphur	....	.002	....	.001	....	....
Phosphorus	.037	.044	.104	.027	.039	.06
Aluminum	.082	.045	.032	.012	....	....
Calcium	.015	.016	.021	....	....	....
	99.999	99.898	100.062	100.010	....	....

Subjoined are some further analyses of spiegel iron given by Hackney in the "Proceedings of the Civil Engineers, April, 1875:"

Analyses of other foreign spiegels.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Iron	89.527	86.000	83.777	....	83.08	....	75.100	70.34	65.81
Manganese	5.619	8.500	11.782	12.000	12.30	18.870	20.350	23.48	28.70
Carbon	4.410	4.00	4.538	4.500	3.90	4.500	3.800	5.31	5.28
Silicon	.161	1.10	.041	.130	.54	1.050	.254	.09	.01
Phosphorus	.047	.288	.084	.075	.08	.102	.029	.37	.38
Sulphur	.017	.03	.010	.010	Trace.	Trace.	.010	Trace.	Trace.
Copper	....	.04	.015	.002	....	.063	Trace.	Trace.	Trace.
Arsenic	.288	....	....	....	....	....	....	....	....
	100.069	99.958	100.247	....	99.90	....	99.543	99.59	100.18

1. Swedish spiegel. Authority: G. J. Snelus, *Journal Iron and Steel Institute*, 1874, page 76.
2. Rhenish spiegel iron, from Spaeter and Wirth, Coblentz. Analyst: A. Willis.
3. Landore spiegel iron. Analyst: E. Riley.
4. Landore spiegel iron. Analyst: A. Willis.
5. West Cumberland spiegel iron. Authority: G. J. Snelus, *loc. cit.*, page 73. Analyst: G. J. Snelus.
6. Dowlais spiegel iron. Authority: G J. Snelus, *loc. cit.* Analyst: W. Jenkins.
7. Spiegel iron made at Schisshyttan iron works, Sweden. Authority: D. Forbes, *Journal Iron and Steel Institute*, 1874, page 467.

Nos. 8 and 9. Spiegel iron from Illyria, Austria, made by the Krainischen Eisen-Industrie Gesellschaft. Authority: D. Forbes, *loc. cit.* Analysts: Of No. 8, M. Lill; of No. 9, H. Sturm.

The percentage of spiegel iron which is introduced into the Bessemer converter or into open-hearth steel varies between 1 and 5 per cent. according to the amount of manganese in the spiegel iron, and also according to the condition of the iron. If the elimination of carbon has been quite complete more spiegel iron will be necessary to combat oxidation and leave the desired quantity of manganese in the finished product. As has been said, a large part of the manganese is driven out of the iron into the slag, but usually about 0.25 per cent. (from 0.1 to 0.8 per cent.) remains in the iron. In an example by Mr. Snelus 251 pounds of spiegel iron containing 8.88 per cent. manganese was added to 72 cwts. of pig iron. If no manganese had been lost 22.288 pounds of this metal would have been found. But only 7.28 pounds were actually found, showing that 15 pounds, or about two-thirds, had been removed, leaving steel containing 0.104 per cent. manganese.

The following determinations of the quantity of manganese in various kinds of steel are given by Kessler in Dingler's *Polytechnische Journal:*

Amount of manganese in steel.

Steels.	Per cent.
Krupp's crucible cast steel (Essen)	0.437 to 0.438
Bochum cast steel	0.312 to 0.317
Hasper steel	0.327 to 0.332
Manganese steel of Ludwig in Berlin	0.303
Fine piano wire	0.035
Hoerder steel	0.107 to 0.170
Cannon steel (Terre Noire)	0.240
Common steel (Barroin)	0.240
Rail steel (Creusot)	0.550
Rail steel (Petit Gaudin)	0.560
Rail steel (Terre Noire)	0.860
Rail steel (Seraing)	0.650

It has been found beneficial in making soft steel to add 1 per cent. of manganese; but as spiegel iron contains 4 to 5 per cent. carbon, too much of this latter substance would be introduced into the steel if spiegel iron were used to furnish the manganese. An alloy called "ferromanganese," containing a larger proportion of manganese and no more carbon, is therefore necessary.

Ferromanganese.—In general, when the amount of manganese in iron exceeds 20 per cent., it is no longer called spiegel iron, but ferromanganese; the distinction is due, however, not so much to the proportion of manganese to iron, but to the process of manufacture. Spiegel iron is made in the blast furnace, and this has been the method of preparing it since its first use in the iron industry. But no matter what proportion of manganese ore is used, it is extremely difficult to introduce more than 10 per cent. of manganese when a flux with considerable silica is used. When a greater proportion was desired it was the custom until recently to resort to one or another modification of a process originated by Bessemer, in which the desired reduction of manganese ores is effected in crucibles. This process, as first introduced on an industrial scale by Prieger, of Bonn, consists in heating a mixture of manganese dioxide, small lumps of cast iron, powder, lime, glass, and charcoal in a graphite crucible. The higher the temperature the richer is the resulting alloy in manganese, so that it is practicable at the highest temperature of a reverberatory furnace to obtain an alloy with 60 per cent. manganese. A process invented by W. Henderson, of Glasgow, and largely used at Terre Noire, dispenses with crucibles. An intimate mixture of manganese carbonate, iron oxide, and powdered charcoal is heated red hot for several hours in the reducing flame of a Siemens furnace. By this means a metallic sponge is obtained. By raising the temperature to white heat, the sponge melts, giving ferromanganese containing 20 to 30 per cent. manganese. Several patents obtained in late years contain only unimportant modifications of these processes. But since 1873 the use of coke in blast furnaces and a highly basic slag has made it possible to produce ferromanganese containing 60, and even 80, per cent. of manganese by the blast-furnace process. The use of coke aids in obtaining a temperature sufficiently high for the reduction of manganese, and the basic slag does not carry off much manganese with it. It was formerly the custom to use manganese dioxide in the blast furnace, but this is reduced to manganic oxide in the upper part of the furnace by carbon monoxide from the reduction going on below. This causes such overheating of the throat of the furnace that the gases cannot be collected. The manganese ores are therefore reduced to manganic oxide in a separate furnace.

The following analysis will show the constitution of ferromanganese: (*a*)

Analysis of ferromanganese.

	Per cent.
Manganese	69.64
Iron	23.45
Carbon	6.21
Silicon	.28
Copper	.14
Phosphorus	.06
Sulphur	Trace.
	99.78

The manufacture of spiegel iron and ferromanganese in the United States.—Up to the present time the greater part of the spiegel iron used in the Bessemer steel process in this country has been imported from Europe. The largest quantity imported in any one year was 25,000 tons. In 1870 the manufacture of spiegel iron was undertaken by the New Jersey Zinc Company, of Newark, New Jersey, which has furnaces each 20 by 7 feet, with a combined annual capacity of 5,000 long tons. The spiegel iron made by this company is said to be equal to the best that is imported, and is therefore readily sold. The following are two analyses of it:

Analyses of American spiegel iron.

	Per cent.	Per cent.
Iron	83.250	83.23
Manganese	11.586	11.67
Phosphorus	.196	.19
Silicon	.367	.99
Carbon	4.62	4.02
	100.031	100.10

It is said that pig iron quite rich in manganese is made at several furnaces in the United States, but not of a quality that will justify its use as spiegel iron. In 1875 the Bethlehem Iron Company and the Cambria Iron Company commenced to make spiegel iron from Spanish ores. In the same year the Woodstock Iron Company, of Anniston, Calhoun county, Alabama, undertook to make spiegel iron from the Alabama ores. The manganese ores which they used contained somewhat over 20 per cent. metallic manganese; these were smelted with iron ore containing 58.25 per cent. iron, 8.56 per cent. manganese, and 1.42 per cent. phosphorus. Samples of the product, taken for analysis on the following dates, were found to have the following composition:

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[a] Hofmann's Entwickelung der Chemie, page 849.

Analyses of spiegel iron from Woodstock, Alabama.

	December 10, 1875.	January 6, 1876.	February 1, 1876.	February 3, 1876.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Iron	85.11	85.98	80.37	73.86
Manganese	10.18	8.14	14.33	20.69
Carbon	3.66	4.83	4.94	4.32
Silicon	.95	.88	.38	.93
Phosphorus	.10	.17	.18	.17
Total	100.00	100.00	100.20	99.97

The enterprise has not proved remunerative at this place; about 2,000 tons of manganese ore were used in all. No spiegel iron was made here in 1883 or 1884. A successful attempt to make spiegel iron was made at the Bessemer works, in Pueblo, Colorado, in 1883. At present the chief producers of spiegel iron are: The Edgar Thomson (Carnegie Brothers) Steel Works, the Bethlehem Iron Company, the Cambria Iron Company, the Brier Hill Iron and Coal Company, the Lehigh Zinc and Iron Company, and the Passaic Zinc Company.

The manufacture of ferromanganese was attempted some years ago at the Diamond furnace, in Georgia. It did not prove successful. The only other attempt to utilize native manganese ores in the production of ferromanganese was made in August, 1884, at the Edgar Thomson Steel Works, at Bessemer, Pennsylvania. At this time, blast furnace A began making ferromanganese instead of spiegel iron. The product is said to contain from 80 to 90 per cent. of metallic manganese, and 92 per cent. has been reached. The daily product is from 45 to 50 tons. Besides supplying their own steel plant, Carnegie Brothers are thus enabled to supply the open-hearth furnaces of neighboring steel works, and it is probable that this new departure will materially lessen, if not suppress, the importation of ferromanganese.

Hadfield's manganese steel.—In ordinary steel the proportion of manganese seldom exceeds 0.5 per cent., and 1.5 per cent. is the maximum which has been added in the ordinary processes of steel manufacture. Recently, however, Mr. Robert Hadfield, of the Hadfield Steel Foundry Company, Sheffield, England, has claimed that steel containing from 7 to 30 per cent. manganese is harder, stronger, denser, and tougher than ordinary steel, even when the latter has been forged and rolled, and in addition he believes this steel to possess properties which will make it exceedingly valuable for many purposes for which ordinary steel is not now used. In order to make this steel, melted ferromanganese (Mr. Hadfield recommends that containing 80 per cent. manganese, and as low as possible in carbon, silicon, and other foreign bodies) is added to iron which has been nearly or quite freed from carbon, or to molten steel. The manganese is thoroughly incorporated by stirring, and the steel is poured into ingots or other suitable molds. The percentage of ferromanganese to be used must be varied according to the use to which it is to be put. No absolutely exact proportions can be given. To produce a steel suitable for armor plates, sufficient ferromanganese to give 10 per cent. of manganese in the steel should be added; for wheels, axles, or railroad plant, say 11 per cent.; edge tools, 12 per cent. It is claimed that the metal when melted is very thin and mobile, casts without misrunning, does not settle as much as ordinary castings, and does not draw, particularly at the junction of the thin and thick parts. The steel is said to be tough without forging, rolling, or hammering. An ingot with 9 per cent. manganese which had not been forged was bent 1½ inches in 2½ feet before breaking. Hammered samples from this ingot gave a tensile strength of 42 tons (94,080 pounds) and 20.85 per cent. elongation. Besides unusual toughness the steel is very hard; specimens containing 9 to 10 per cent. manganese can be drilled, etc., but not so readily as ordinary steel, while it is practically impossible to drill or turn those containing higher percentages. An ax made from 19 per cent. steel cut through ⅝-inch iron. If future investigation of such manganese steel shows that it can be made regularly with the properties claimed for it, there is little doubt that it will be a valuable addition to the varieties of hard steel now in use.

Other alloys of manganese.—Alloys of copper, such as brass and bronze, may be rendered denser and harder by the addition of manganese; if more than 8 per cent. of manganese is added its presence is indicated by the gray color of the alloy, which then becomes brittle. A beneficial effect is also observed when manganese is added to bronze or brass which is impure from the presence of copper oxide; manganese oxide is formed, which rises to the surface and may be removed. These alloys of manganese have received considerable attention in England in late years and have come into quite extensive use in the place of gun metal for main bearings, top and end brasses, crank pins, etc., on large steamers, and it is probable that the extension of the manganese interests will be in this direction during the next few years.

CHROMIUM.

BY DAVID T. DAY.

History of the chromium industry.—Just as the industry of nickel and cobalt has been developed entirely in one locality, Camden, New Jersey, so the chromium industry has found its development entirely in the neighborhood of Baltimore, Maryland, and one firm has been instrumental in bringing it to its present condition, although the industry has spread to the Pacific coast, and the firm has reached the fourth generation. About sixty years ago it became known to Mr. Isaac Tyson that chrome iron ore occurred on his farm at Bare Hills, Baltimore county, Maryland. His son, also named Isaac Tyson, who was engaged in the mining business, began working out the ore and shipped it to England. In 1833 he entered into an agreement with an Englishman of reputed scientific ability to begin the manufacture of paints, for which the chrome ore was decomposed and transformed into various pigments. The knowledge of the Englishman proved inadequate, and the venture was not successful. Mr. Tyson, although actively engaged in business pursuits, then began to study the various processes for working up chrome ore and similar substances, supplying the want of scientific training by most assiduous study of the scattered literature which France and other countries could furnish relative to such subjects. Meanwhile chrome ore was again shipped to England, this being the only demand for it until about 1843. The deposits at Bare Hills never furnished much ore; they were rapidly exhausted, and, the trade with England being once started, inquiry was made for new deposits. Wherever ore was reported it was at once investigated, and, if valuable, controlled by Mr. Tyson. In this way ore was discovered and worked out in large quantities at Soldier's Delight, Baltimore county. In Harford county an enormous deposit was found which furnished ore steadily for more than forty years. In Cecil county ore was again found, and another large deposit at Wood's mine, Lancaster county, Pennsylvania. When this deposit and others in Delaware and Chester counties were reached, Mr. Tyson feared that more mines might be discovered than could be operated by himself, the English market might become overrun with ore and leave no sale for his own product in Maryland. To make an independent market, therefore, for his ore, Mr. Tyson again applied his study to manufacturing, and with such phenomenal success that the works established in 1845 for utilizing chrome ore still monopolize the chromium industry in the United States. At first the yearly amount of chromium salts made was insignificant, but gradually they replaced the importation from England, until finally the Baltimore chrome works supplied this country entirely.

The secret of success in the "Tyson works" lies in some unpublished feature of their method of decomposing chrome iron ore. This substance resists the action of most chemical agents to an exceptional degree. Until the year 1820 chrome iron ore was decomposed by roasting with potassium nitrate (niter). In that year Köchlin introduced certain chromium salts in the process of Turkey-red dyeing, and they soon were employed for a variety of purposes, especially in connection with dyeing wool. The increased consumption led to improvements in the decomposition of the ore, and potassium carbonate was introduced in the manufacture, instead of potassium nitrate; the oxidation was effected by atmospheric oxygen in reverberatory furnaces. About the year 1845 an important improvement was made by Stromeyer in the introduction of a certain quantity of lime together with potassium carbonate. Not only was a saving of alkali effected, but the oxidation was rendered easier, inasmuch as the whole mass did not fuse, and therefore remained porous and more capable of absorbing the atmospheric oxygen.(*a*) As at present understood, therefore, the decomposition of chrome ore consists in powdering the mineral by means of good millstones, heating it for some hours in a reverberatory furnace with potassiam carbonate and lime in certain proportions, and dissolving out the chromium from the fused mass by water, in the form of potassium chromate, which is converted into bichromate by sulphuric acid. This operation is put down in the text books as comparatively simple; but in the past twelve years no less than fifteen attempts have been made to establish works for decomposing chrome ore, in Philadelphia, New York, and Boston. It is, however, an extremely difficult matter so to regulate the manufacture as to produce potassium bichromate at the present market price. This, by long experience and devices known to itself, the Baltimore firm is able to do.

Domestic sources.—Chromium is found in irregular deposits in several widely separated districts in the United States. Its presence is usually indicated by the associated serpentine rock. The two districts which have an important bearing on the industry are located one in Maryland and Pennsylvania and the other in California. Of these the Maryland district begins in the Green Spring valley, in Baltimore county, and extends through Harford and Cecil counties, ending in Lancaster, Delaware, and Chester counties, Pennsylvania. In this district the deposits occur irregularly through the counties named. Bare Hills and Soldier's Delight, near Owen's Mills, in Baltimore county, have furnished somewhat more than 5,000 tons of sand ore. Reed's mine, in Harford county, furnished over 100,000 tons. Wood's mine, in Little Britain township,

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a Roscoe and Schorlemmer's Treatise on Chemistry, Vol. II., part 2, page 171.

Lancaster county, Pennsylvania, is an old and well-known deposit, from which considerable ore has been sent to Baltimore. Low's, Linepit's, and Jenkins's mines are also noted deposits, in Fulton township, Lancaster county. In Chester county chromium is found in Elk and Nottingham townships. It is also found in Middletown and Marple townships, Delaware county, Pennsylvania.

A few isolated occurrences of chromium ores have been noted, though not mined, in States north of the Maryland district: in New York, at Phillipstown, Putnam county, and at Wilke's mine, Monroe, Orange county; in Massachusetts, in Blandford and Chester townships, Hampden county; in Vermont, in Jay, Troy, and Westfield townships, Orleans county.

South of the Maryland district chromium is found in Virginia, at Drainesville, near the Potomac, in Fairfax county. Quite recently a deposit of chrome ore was reported in Jackson county, North Carolina, which, as stated in the last report, promised to yield ore of better quality than any other in the eastern States. The deposit has not, however, been worked up to the present. Chrome ore is known to occur in small quantity in North Carolina, in Guilford county; at Cullasaja, Higdon's, Elijay's creek, and Moore's mine, Macon county, and in Yancey, Clay, Mitchell, Burke, and Watauga counties.

Until about three years ago, the Maryland district included in it nearly all the mines from which chromium was obtained, but since then an entire change has been made in the supply. The eastern mines have been practically abandoned, and now all the ore comes from the more recently discovered deposits in California. Fifteen years ago Messrs. Tyson & Sons were informed by their attorney in West Chester, Pennsylvania, that his brother, living in Del Norte county in the extreme northwestern part of California, had discovered chrome ore on his farm. About this time Mr. Simpson, a Baltimore merchant, urged the Tysons to aid him in working gold mines of reported immense value in Arizona. A surveyor was sent by the Tysons to Arizona with Mr. Simpson to investigate the supposed gold deposits. They proved worthless, and after Mr. Simpson had been killed by hostile Indians, the surveyor thought it best to investigate another region and examine the reported chromium deposits in California. They proved to be hornblende rock without value, but by a mere accident, which has always been a feature of chromium discoveries, he found a large deposit of chrome iron ore in another part of the county. For some years past the deposit has been worked and large quantities of ore have been extracted by the Tyson Mining Company, and as yet there are no signs of exhaustion in this field. Following the discovery in Del Norte county came that of ore in Sonoma, San Luis Obispo, and Placer counties; and chromium is now known to be common throughout California, having been noticed in more than half the counties of the State. The undeveloped deposits and mere croppings are, in fact, too many to admit of their enumeration here. Chromium also occurs elsewhere on the Pacific coast, but to what extent or of what quality has not been determined, no attempts at utilizing it having been made except in California, where it has been mined and shipped to eastern markets at the rate of about 3,000 tons per year since its discovery. The deposits in California most entitled to notice, because of their magnitude, good grade, or the extent to which they have been worked, are the following: Near Litton Springs, Sonoma county, from which there were extracted some years ago about 2,000 tons of ore, cost of mining and delivering at San Francisco about $4.50 per ton, average price obtained about $9 per ton; Sow Divide copper mines, Del Norte county, from which there were taken some years ago several thousand tons of good chrome ore—no work has been done there lately; Campo Seco, Calaveras county, a good article and in large quantity. This last-named deposit can be worked to good advantage when the narrow-gauge railroad now in course of construction shall reach Campo Seco. In San Diego gulch, in the same county, there is said to be an isolated mass of chrome iron that will weigh thousands of tons. From the chrome mines of San Luis Obispo county the largest amount of ore has been shipped, the total exceeding 15,000 tons. This was a number of years ago, no shipments having been made lately from that county owing to the low prices of chrome ore. Most of the chrome now being extracted in California comes from Placer county, from which shipments have averaged in 1883 and 1884 about 2,000 tons per annum. Just now this industry is much depressed in California, but with prices slightly improved it would more than regain its former activity. All of the sources utilized are as a rule worked by the Tyson Mining Company. Other companies are also engaged in the work of extracting ore in a small way. It is taken by wagons to the nearest railroad and transported to San Francisco. If not already the property of the Tysons it is all bought by them and shipped in sailing vessels by way of Cape Horn to Baltimore. A small amount is exported.

At present there is no indication of exhaustion in the California mines, and yet every effort is being made to discover new deposits, for the reason that these deposits are not found in veins or leads from the direction of which new mines can be predicted, but in isolated pockets of all sizes, sometimes yielding only a few pounds and sometimes many thousand tons. The miner is never sure but that the next day may find his deposit exhausted or the quality of the ore no longer profitable. The only rule that has been found is that the ore is richest at the surface and decreases in value as the mine become deeper. The value of a mine decreases very rapidly with the depth; for, in addition to the cost of getting ore to the surface and of keeping out water from the mine, the ore contains less chromium. The mines in the eastern States are by no means exhausted; the reason why the California ores have been substituted is because they are nearer the surface and therefore richer. As the cost of grinding and decomposing the ore is the same for rich as for poor grades the rich ores are more profitable; moreover the higher the percentage of chromium in the ore the easier is its decomposition.

The general results of over one hundred analyses of ore found in California may be given as follows:

	Chromic oxide.
	Per cent.
Del Norte county	39 to 45
Napa county	42 to 46
Placer county	35 to 55
Tuolumne county	44 to 45
San Luis Obispo county	38 to 60
El Dorado county	20

Foreign sources.—Ores of the same character as those of California are found in Turkey, Russia, and Asia Minor. From this last source a small quantity of ore annually finds its way to Baltimore. The amount, however, is small and irregular. Nearly all the ore which supplies the Scotch and French manufactories of chromium salts comes from Russia. The ore is mined in Siberia and transported to St. Petersburg on rafts down the various watercourses. These rafts start on their journey in the spring, are frozen up all of the next winter, and reach their destination the second summer. The rafts are sold for lumber and the ore is shipped to England. By this means ore is mined in a remote region at small expense; without this cheap system of rafting competition with American ores would be impossible.

Character of the ores.—Chromium occurs as a constituent of several minerals. Crocoite, for example, is chromate of lead; the green color of the emerald is due to traces of chromium; while penninite, chromic mica or fuchsite, and other minerals owe their color to this metal. But the ore from which chromium is always obtained is chromite or "chrome ironstone." Its composition may be expressed by the formula $FeCr_2O_4$; but part of the chromium may be replaced by iron, or the iron may be partly replaced by magnesium, and the replacements are found in ore far removed from the surface of the ground. Aluminum is also sometimes present, and silica is often found in the sand ore, or ore containing the chromite in the form of small grains. The purest ore is found in lumps weighing sometimes several pounds.

Production.—The following table represents about the amount of ore mined in the last three years; it is all from California:

Production of chrome ore in California.

Years.	Tons of 2,240 pounds.	Value in California.
1882	2,500	$50,000
1883	3,000	60,000
1884	2,000	35,000
	7,500	145,000

There is no regular spot value for chrome ore at the mines, as the cost varies irregularly in each district and much is mined by the manufacturers' agent who owns the mine. In San Francisco the ore is worth from $18 to $20 per long ton. By the time it reaches Baltimore the cost is from $35 to $40 per long ton. The total amount expended therefore for chrome ore in 1883 and 1884 was about $190,000.

Exports.—The value of ore exported from 1864 to 1883 is given in the following table:

Value of chrome ores exported from the United States, 1864 *to* 1883 *inclusive.*

Fiscal years ending June 30—	Value.
1864	$39,585
1865	19,078
1873	2,080
1874	4,288
1880	7,540
1882	1,548
1883	2,905
1884	(*a*)

a None reported.

Utilization.—Nearly all of the chrome ore used in the United States is made into potassium bichromate by Jesse Tyson & Sons, at Baltimore. About 50 tons a year is made into chrome steel at the Brooklyn Chrome Steel Works. Potassium bichromate is therefore the one salt from which all other compounds have been obtained. The amount of potassium bichromate produced in the United States is in all about 1,500 tons a year. Of this, a small quantity, amounting to about 250 tons a year, is made by Harrison Bros., who have been making bichromate for about three years past at the branch of their color works called the Kalion Works, Philadelphia.

Imports.—Besides the domestic product about 1,000 tons of bichromate are annually imported from Scotland under a duty of 3½ cents per pound. Chromic acid, which is obtained from the bichromate, is also imported in small amounts; it would probably become a more extensive article of commerce except for the danger of its setting fire to vessels and storehouses. The following table gives the actual amounts imported and their value from 1867 to the end of the fiscal year 1884:

Chromate and bichromate of potash and chromic acid imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Chromate and bichromate of potash.		Chromic acid.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1867	875, 205	$88, 787	....	....	$88, 787
1868	777, 855	68, 634	....	....	68, 634
1869	877, 432	78, 288	....	$3	78, 291
1870	1, 235, 946	127, 333	....	8	127, 341
1871	2, 170, 473	223, 529	....	5	223, 534
1872	1, 174, 274	220, 111	514	49	220, 160
1873	1, 121, 357	178, 472	922	276	178, 748
1874	1, 387, 051	218, 517	44	13	218, 530
1875	1, 417, 812	183, 424	45	22	183, 446
1876	1, 665, 011	175, 795	120	45	175, 840
1877	2, 471, 669	264, 392	13	10	264, 402
1878	1, 929, 670	211, 136	32	35	211, 171
1879	2, 624, 403	221, 151	....	....	221, 151
1880	3, 505, 740	350, 279	5	3	350, 282
1881	4, 404, 237	402, 088	124	89	402, 177
1882	2, 449, 875	261, 006	52	42	261, 048
1883	1, 990, 140	208, 681	290	338	209, 019
1884	2, 593, 115	210, 677	....	120	210, 797

Sodium bichromate.—On account of the less cost of sodium carbonate it has frequently been proposed to substitute it for potassium carbonate in the decomposition of chrome iron ore, and thus produce sodium bichromate instead of the potassium compound. There are several obstacles to this: The decomposition is not as readily affected with sodium carbonate as with potash, and, further, sodium bichromate is by no means as easy to crystallize as the potassium salt, and in fact it is with great difficulty that sodium bichromate can be crystallized at all. But about three years ago the manufacture of sodium bichromate was introduced by German chemists, and the effect on the industry can already be seen. Before this German innovation, factories in Scotland and France supplied Europe with chromium salts. The introduction of sodium bichromate has brought about competition with Germany, amounting to a chromium war. The Scotch and German manufacturers are trying each to drive the other from the field. In 1882 the price of potassium bichromate was 15½ cents per pound. In 1883 it fell to 12 cents, and it now is selling in this country at 10½ cents, the lowest price it has ever reached. What the outcome of this competition may be can be surmised from the fact that within the last few months the Baltimore firm has begun the manufacture of sodium bichromate, though only as an experiment so far. For many purposes sodium bichromate can take the place of the potassium salt without disadvantage. For example, in any use where the oxidizing action of the salt is the only point to be considered, as in the manufacture of Turkey red, or alizarine, one salt is as useful as the other. The most important application of potassium bichromate in the arts is for calico printing. For this purpose dyers prefer potassium bichromate to sodium bichromate. In how far this is mere prejudice it is not possible to say. In the manufacture of pigments, in which bichromates find application for making "chrome yellow," "chrome orange," and "chrome green," either salt can be used.

TUNGSTEN.

By David T. Day.

The only source of tungsten discovered since the list of localities was published in "Mineral Resources of the United States, 1882," page 431, is at Irish creek, Rockbridge county, Virginia. The occurrence of wolframite at this place was discovered by Mr. W. G. Brown and announced in the *American Chemical Journal*, Vol. 6, page 185. It is found with cassiterite in the closest connection with quartz. The tin-bearing veins in which the wolframite is found, have been followed to a depth of from 12 to 20 feet. They run northeast and southwest conformably with the common strike of the rocks of the Blue Ridge, but sometimes nearly at right angles to this. The wolframite is found in rough crystals or irregular masses, mixed with the products of its disintegration, in all stages of weathering, from the almost fresh unchanged mineral to red ocher. In some specimens the cassiterite is wholly imbedded in these decomposition products. The Charles Lane mine, at Monroe, Fairfield county, Connecticut, is regarded as the most important source of tungsten in the United States. In this mine wolframite and scheelite occur with the sulphides of iron and copper. The mine has been worked for gold and argentiferous galena, and wolfram is sometimes saved. In 1872 about 1 ton of wolfram was mined. This was the largest amount ever obtained at one time, though several small quantities have been mined since, chiefly for experimental purposes. In 1874 the Booth mine, located 1½ miles due east of the Lane mine, was opened, and since then indications have been obtained of larger amounts of tungsten minerals than in the Lane mine, but none has been mined. The information in regard to these deposits is due to Mr. Minot Booth, of Monroe, Connecticut. No effort has been made to mine the small amount of wolfram and other tungsten minerals known to exist at Mine la Motte, Missouri. About 30 pounds of wolfram have been obtained from the Einstein silver mines, 10 miles west of Fredericktown, Missouri.

There has been some inquiry for tungsten minerals during 1884, which brought out the fact that dealers can furnish powdered wolframite containing 39 per cent. tungstic acid for 12 cents per pound. It can also be imported at 8 cents per pound containing 35 to 55 per cent. tungstic acid. The chief impurities in the imported ore, which is an important consideration for use in making steel, are given in the following analysis:

Partial analysis of German wolframite.

	Per cent.
Tungstic acid	57.26
Iron	11.08
Manganese	7.03
Sulphur	.49

It is understood that an attempt is about to be made to manufacture steel containing a small amount of tungsten in one of the steel works near Philadelphia. It is evident from the amount of sodium tungstate sold in England and Germany, for rendering fabrics and even woodwork fireproof, that this use of tungsten is increasing.

PLATINUM.

Domestic sources.—Platinum has been found in small quantities in various parts of the country, associated with free gold in placer deposits. Indeed its distribution has been almost co-extensive with these deposits, but in most localities the quantity is altogether too small to admit of economic working, and it is only from the placers of the Pacific slope, north of the Central Pacific railroad, that it has been produced in merchantable quantity. The following are the localities at which most of the platinum heretofore collected in California has been procured: Hay fork, a branch of the Trinity river, occurring here in fine grains, mixed with the placer gold, to an extent sometimes sufficient to reduce the value of the gold by 8 to 10 per cent.; on the North fork of the Trinity platinum is less plentiful but occurs in larger grains, the largest pieces ever found weighing between 2 and 3 ounces; in Butte county, in the hydraulic mines around Cherokee and Oroville, occasionally for nine parts of gold found in this locality one part is found of platinum and its allied metals; in Mendocino county, in Anderson valley, Novarro river; in Plumas county, on the principal forks of Nelson creek and at Badger and Gopher hills; on the Salmon river, and in the beds of the larger streams in Sierra, Trinity, and Del Norte counties; on the ocean beach between capes Blanco and Mendocino; on the Merced and Tuolumne rivers. Going farther north the amount of platinum increases. On the Oregon coast the proportion of gold to platinum in the placers is sometimes 5 to 1, and in rare instances the amount of platinum equals the gold. Platinum has been reported as occurring in Idaho, and in the Black cañon, and on the Agua Frio, in Arizona, though the occurrence in the latter Territory is not well authenticated.

Foreign localities.—The most important sources of platinum are the hydraulic mines at Nizhne-Tagihlsk and Goro-Blagodat, in the Ural mountains, where the ore is found with chrome-iron ore in serpentine. About 80 per cent. of the world's production comes from this source. Next in importance are the gold washings of the Pinto, in the province of Antioquia and the headwaters of the Atral river in the United States of Colombia, where it is bought by the traders in inland towns and sent to Buenaventura, thence to Paris; about 15 per cent. of the entire product comes from this source. In Brazil the ore is found in the province of Minas Geraes, associated with syenite. It is found also in the Natoos mountains in Borneo, in Hayti, Peru, India, Australia, and in the sands of the Chaudiere river in Quebec. It has been noticed lately in a quartz vein impregnated with gold-bearing iron pyrites, which was struck when deepening the shaft of the Queen of Beauty Gold Mining Company's mine, Thames gold district, New Zealand. The interest in this deposit lies in the fact of the extreme rarity of platinum ores in place.

Character of the ore.—Platinum "ore," as it is called, contains all the metals of this group, together with iron, copper, titanic iron ore, etc. It is sometimes, though seldom, found crystallized in cubes and octohedrons, but more usually in rounded or flattened grains or "sand" having a metallic luster; occasionally in large nuggets. The ore is very rarely found in place, but mixed with placer gold sands. The specimens containing the largest proportion of platinum have been found in Brazil. The following are analyses of platinum ores made by Deville and Debray. (*a*) California ore sometimes yields the refiner only 50 per cent. of its weight in pure platinum.

Analyses of platinum ores.

	Chico, South America.	California.	Australia.	Urals.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Platinum	86.20	85.50	61.40	76.40
Gold	1.00	.80	1.20	.40
Iron	7.80	6.75	4.55	11.70
Iridium	.85	1.05	1.10	4.30
Rhodium	1.40	1.00	1.85	.30
Palladium	.50	.60	1.80	1.40
Copper	.60	1.40	1.10	4.10
Osmiridium	.95	1.10	26.00	.50
Sand	.95	2.95	1.20	1.40
Total	100.25	101.15	100.20	100.50

The substance termed osmiridium (iridosmine) is an alloy of osmium and iridium, which is separated by its insolubility in nitro-hydrochloric acid. The sand mentioned contains quartz, chrome-iron ore, hyacinth, spinel, and titanic iron.

Production.—As early as twenty-five years ago the miners of California, finding small quantities of platinum sand in their sluices with the gold, were induced to collect and save it, under the impression that it commanded a higher price than was actually the case. Hence, during the first few years of placer mining in the State several hundred ounces of platinum, alloyed and mixed with the other associate metals, were annually sold in San Francisco. Latterly, however, with the decrease in hydraulic mining, the amount has been much less, reaching not more than 100 or 200 ounces per annum. For this platinum sand 75 cents per troy ounce is paid, the purchaser (there is but one at present at San Francisco) shipping it to London. No attempt has been

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[a] "Annales de Chimie et de Physique," third series, Vol. 56, page 449.

made in San Francisco to refine the sand or to put it in shape for manufacturing.

The production of platinum in the United States during 1883 is estimated at 200 troy ounces, and in 1884 at 150 troy ounces.

Imports.—The platinum used in this country comes almost entirely from Russia, principally through the agency of Johnson & Mathey, of Covent Garden, London, who have been for many years the largest re-refiners of platinum in the world. Occasional importations are also received from Quennessen, Le Brun, and F. Desmontis et Cie., Paris. A trifling amount of ore is imported from Buenaventura, South America, and refined, with other platinum, by Baker & Co., of Newark, New Jersey. The other dealers either import altogether or manufacture platinum vessels from plate and scrap. From one-half to three-quarters of the importations consist of platinum ranging from chemically pure to that containing 1 per cent. of other metals. Nearly all of the balance is alloyed with 5 per cent. of iridium, for the purpose of making it harder and more elastic; while a small proportion contains a little higher percentage of iridium, ranging as high as 10 per cent. of the latter metal. The price of refined platinum has risen steadily during 1883 and 1884. In the early part of 1883 the importers' price was $6.50 to $7.50 per troy ounce, according to the quantity bought; at the close of 1884 the price was $7.50 to $8.50. The following table gives the importations from 1867 to 1884:

Platinum imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive*.

Fiscal years ending June 30—	Manufactures of.	Unmanufactured.		Vases or retorts, etc.
		Quantity.	Value.	
		Pounds.		
1867	$456			
1868	290		$95, 208	$20, 274
1869	184		80, 014	22, 004
1870	648		99, 984	16, 294
1871	48		108, 244	22, 470
1872	310		91, 472	21, 816
1873	43		90, 771	9
1874	143		123, 293	59, 698
1875	173		141, 188	18, 082
1876	6		141, 207	7, 421
1877	11		81, 925	18, 611
1878	241		120, 121	50, 133
1879	73		166, 178	34, 209
1880	964		217, 144	41, 827
1881	290		273, 343	21, 292
1882	1, 731	3, 125. 60	285, 731	48, 452
1883	4	3, 104. 15	298, 799	92, 967
1884	None.	2, 846. 00	289, 898	83, 112

Exports.—Platinum is occasionally exported, principally in the form of used-up sulphuric acid stills which are sent to Europe for repairs. Some scrap is also exported. The following table gives exports since 1880:

Value of platinum exports.

Fiscal years ending June 30—	Unmanufactured.	Manufactured.	Old platinum.
1880			$600
1881			4,222
1882		$19,244	
1883	$6,250	21,600	
1884		18,587	1,130

Uses.—The principal consumption of platinum is in the manufacture of chemical apparatus. In the form of various utensils, such as evaporating dishes, crucibles, retorts, funnels, spatulas, combustion boats, blowpipe tips, foil and wire, platinum forms an essential though usually small part of the equipment of every chemical laboratory, on account of the high temperature at which it melts and its property of resisting the action of acids. Platinum enters also into the field of chemical industries in some cases where laboratory operations have assumed manufacturing proportions. Particularly in the concentration of sulphuric acid large evaporating dishes and retorts are used by perhaps more than half of the manufacturers in this country and England. Where platinum vessels are not used in sulphuric-acid manufacture iron and glass are substituted. The comparative advantages and disadvantages of these kinds of vessels have left neither markedly in preference. Platinum vessels are used in sulphuric-acid manufactories where care is taken to produce an acid which contains no nitric acid, for the latter slowly dissolves the metal under these conditions. When cracks occur in the dishes they are soldered with gold; after this the corrosion goes on faster than before, due it is claimed to galvanic action set up by the gold and platinum. When much sulphate of lead is present in the pans it exerts a grinding action on the dish and shortens its term of usefulness. By careful handling, however, it has been found profitable to use platinum in spite of the original cost and gradual waste. Platinum is very useful also for making many instruments of precision, especially standard weights and measures; for the latter an alloy of platinum and iridium is used. In Hofmann's report on the Vienna Exposition of 1873, an account is given of the effort to use platinum as coin. Previous to 1827 the Russian government established a large refinery for platinum with a view to working up the ore found in the Urals, but the uses for the metal were so limited that 396 pounds had accumulated in the mint by 1827. To dispose of this surplus it was sent out as coin. No one was obliged to accept it, and it soon became unpopular because of the fluctuations in the market value of platinum. The difference between the face and market value of the coins became so great that in 1845 the Government was forced to redeem the coin. In all 4,146,504 rubles were coined, and 3,263,292 returned to the treasury. With the stoppage of the coinage the annual yield fell from an average of 3,600 pounds to 1,440 for the next ten years. In 1858 a Russian commission assembled to reconsider the question of platinum coinage, in order to dispose of the large amount in the treasury. They decided against the coinage, however, from the experience of the former attempt. The purification of platinum by the mint was then abandoned, and since that time the crude platinum industry has been free in Russia and the refining is carried on in other lands. The following statistics serve to show the fluctuations in the annual yield of platinum ores in the Urals:

Yield of platinum ores in Russia.

	Pounds avoirdupois.
Previous to 1827	600
1827 to 1842 inclusive	54,000
1843	7,560
1844 to 1861 inclusive	24,480
1862	5,113
1863	1,082
1864	872
1865	4,997
1867	3,887
1871	4,506

Platinum is used for pins in artificial teeth. Vessels of copper, brass, etc., may be plated with platinum by welding the platinum foil to the other metals. Dishes made in this way withstand the action of acids even when the coating is very thin, but they are apt to scale when heated highly. They have not come into use because of the care necessary in making them. Tips of lightning rods are frequently plated with platinum. Finely divided platinum is used as a luster in porcelain painting. Reflecting surfaces on glass have been made quite successfully with a thin coating of platinum. By polishing a surface of glass and using a coating on this for direct reflection, mirrors can be made even when the glass is somewhat imperfect; such mirrors in certain physical instruments have the advantage of transmitting just enough light to enable observations to be made conveniently through the mirror.

As an addition to other metals platinum has never been markedly useful. It is itself rendered more suitable for instruments of measurement by the addition of iridium, usually in the proportion of nine parts of platinum and one part of iridium. This alloy is harder and less fusible than pure platinum, and compares with steel in elasticity. If the proportion of iridium reaches 20 per cent., the alloy is scarcely attacked by nitro-hydrochloric acid.

These uses, though numerous, do not consume a large amount of platinum, and the extension of the industry must be looked for in new uses sufficient to consume the quantity of the metal which the known sources can furnish. Lately the use of incandescent electric lights and also gas jets made luminous by a heated platinum spiral have caused an increased demand for the metal, and the steady rise in price during the last two years may be referred to this cause.

IRIDIUM.

By William L. Dudley.[a]

In the year 1803, Smithson Tennant, while investigating the metallic residue which remained when platinum ores were dissolved in aqua regia, thought he had discovered a new metal. Descotils, Fourcroy, and Vauquelin were at the same time examining similar residues, and they also came to the conclusion that a peculiar metal was present; but, however, in 1804, Tennant announced to the scientific world that he had proved the presence of two new metals in these platinum residues, to one of which he give the name of *iridium*, on account of the iridescence of some of its compounds; and to the other, the name of *osmium* (derived from the Greek ὀσμή, smell), because of the peculiar odor which its volatile oxide possessed.

Occurrence.—The geographical distribution of this metal is quite wide; it is found in California, Oregon, Russia, East India, Borneo, South America, Canada, and Australia, and in small quantities in France, Germany, and Spain. The principal source of supply, however, is Russia, where it is found associated with platinum and gold in the placer mines of the Ural mountains. Iridium is found in considerable quantities in the platinum ores, in the forms of platiniridium, which is an alloy of platinum and iridium, and osmiridium or iridosmine, which is an alloy of osmium and iridium. The platiniridium occurs in grains, and sometimes in small cubes with rounded edges. The iridosmine is usually found in the form of flat, irregular grains, and occasionally in hexagonal prisms. The composition of these minerals is shown in the following analyses:

Analyses of platiniridium and osmiridium.

	Platiniridium.		Osmiridium.			
	Urals.	Brazil.	Urals.	New Granada.	California.	Australia.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Iridium	76.80	27.79	55.24	57.80	53.50	58.13
Osmium	....	Trace.	27.32	35.10	43.40	33.46
Platinum	19.64	55.44	10.08	....	......	....
Rhodium	....	6.86	1.51	.63	2.60	3.04
Ruthenium	....	....	5.85	6.37	.50	5.22
Palladium	.89	.49	Trace.	....	....	....
Iron	....	4.14	Trace.	.10	....	....
Copper	1.78	3.30	Trace.	.06	....	.15
	99.11	98.02	100.00	100.06	100.00	100.00

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[a] A portion of the material here presented has been published in a paper read before the American Institute of Mining Engineers, at the February meeting, 1884.

It is impossible to obtain any accurate data as to the production of the metal, for the reason that in Russia the Government endeavors to take possession of all the ore which is mined or extracted from the platinum ores, and it is stored in the vaults of the imperial mint. It is said that the reason for this is that some years ago speculators were in the habit of adulterating gold dust with finely divided iridium ore, which frequently escaped detection until it had caused great damage to the machinery used in coining. Much of the platinum ore which is mined in the Ural mountains is refined in Germany, France, and England, from whence comes most of the iridium used in this country. California promises to be a source of supply, as soon as the demand for the metal is such as to justify the miners in prospecting for it. At present most miners are completely ignorant of the properties and value of the mineral, and in consequence it is thrown away as refuse. On the authority of Mr. Henry G. Hanks, State mineralogist of California, iridium, iridosmine, platiniridium, and platinum are found quite abundantly in the river sands of the northern counties of that State. Considerable quantities accumulate in the mints and assay offices, obtained from the crucibles in melting placer gold.

Iridium ore is a source of great annoyance when mixed with gold-dust on account of its specific gravity, which is about 19.3, being nearly the same as that of gold. Consequently, it is impossible to separate the gold from the iridium by the process of washing; the separation may, however, be made either by the amalgamation of the gold (as neither iridium nor its ores combine with mercury), or by dissolving out the gold in aqua regia.

In the mints these metals are frequently separated by melting the gold dust and allowing the molten mass to remain in the crucible for some time, during which the iridium slowly settles to the bottom, as it does not alloy with the gold under such circumstances. The gold is then poured off from the top, and the dregs in the bottom of the crucible are found to contain the greater quantity of the iridium. The gold contained in the dregs is then dissolved and the iridium remains in the residue.

In the San Francisco mint 150 to 300 ounces of iridosmine is accumulated annually.

Iridium is also found in the Brazilian placer gold, but no data as to the quantity can be obtained, for the reason that few of the placer regions in Brazil are systematically worked, the gold being collected mostly by straggling miners.

Iridium imported and entered for consumption in the United States, 1873 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.
1873	$429
1874	275
1875	500
1876	180
1877	311
1879	425
1881	1,730
1882	7,307
1883	495
1884	(*a*)

a None reported.

Properties.—Iridium possesses a white luster, resembling that of steel; its hardness is about equal to that of the ruby; in the cold it is quite brittle, but at white heat it is somewhat malleable. It is one of the heaviest of metals, having a specific gravity of 22.38. When heated in the air to a red heat the metal is very slowly oxidized; but upon raising the temperature to about 1,000° C., it parts with its oxygen, and hence at a high heat (above 1,000° C.) it is not oxidized. It is insoluble in all single acids, but is very slightly soluble in aqua regia after being heated in the state of fine powder for many hours. In a massive state, however, aqua regia does not attack it. When an alcoholic solution of the sulphate of iridium is exposed to sunlight, it deposits an impalpable black powder, which has the very peculiar property of setting fire to a piece of paper saturated with alcohol when brought into contact with the slightest trace of it.

Iridium is one of the most difficultly fusible of the metals, as will be seen from the following partially successful attempts to fuse it. In Gmelin's "Hand-book of Chemistry," Vol. 6, we find the results of some of these experiments: "Vauquelin fused it in very small quantity only, on charcoal ignited in a stream of oxygen, and obtained a somewhat ductile globule." This could not have been pure iridium if the globule was ductile, as he states. "Children fused it by his galvanic battery into a white, strongly lustrous, brittle, and still somewhat porous globule of specific gravity 18.68. This globule probably contained platinum (Berzelius). One gram of iridium, heated upon charcoal before Döbler's oxyhydrogen blowpipe, fuses into a bright globule, which, however, appears to absorb gas, since, on solidifying, it throws out excrescences, and cavities are formed in its interior." Platinum, which melts at a much lower temperature than iridium, was first fused by Dr. Hare, of Philadelphia, the inventor of the oxyhydrogen blowpipe. He succeeded in melting about 2 pounds (971 grams) at one time. He was also the first to melt iridium by this means.

As was before stated, the iridium which these old chemists claimed to have melted, must have been impure, containing metals of lower melting points; since one says he "obtained a somewhat ductile globule," and another found the specific gravity to be 18.68; when it is well known that pure iridium, in the cold, is not in the least ductile or malleable, and its specific gravity is 22.38. Alloys of platinum, with a small percentage of iridium, can be comparatively easily melted by the oxyhydrogen blowpipe. In a late determination Violle estimates the melting point of pure iridium at 1,950° C., and platinum at 1,750° C. By the use of an electric furnace a small quantity of iridium can be fused at a time, and the result is a porous globule.

In 1881 John Holland, of Cincinnati, Ohio, patented a process for fusing iridium with phosphorus. He found that by heating iridium or any of its ores in a Hessian crucible to a white heat, and then adding phosphorus, the phosphorus rapidly combined with the iridium, and in a few seconds the contents of the crucible were in a perfect state of fusion, capable of being poured and cast into an ingot. This material was found on physical examination to be as hard as pure iridium, and, in fact, seemed to have all the properties of the metal itself. A chemical analysis of two specimens, by Prof. F. W. Clarke, showed the following percentages of phosphorus:

	Phosphorus.
	Per cent.
Sample No. 1	7.52
Sample No. 2	7.74

This product can be remelted indefinitely without any apparent loss of phosphorus.

As the presence of the phosphorus renders the metal quite readily fusible at a white heat, it is found necessary in some cases to remove it, especially where the metal is to be subject to great heat. This may be accomplished by heating the metal in a bed of lime at a moderate temperature, which is gradually increased, the final heating being made in an electric furnace with a lime crucible. By this means the phosphorus can be completely removed, leaving the iridium in a pure state.

If iridosmine is treated with phosphorus as described above, the product will contain no osmium, that metal having been eliminated by the addition of the phosphorus during the heating.

Methods for working and uses of iridium.—The natural grains of iridosmine are used exclusively for the points of gold pens. The iridium point is commonly called "diamond point" upon a gold pen, and it consists simply of a small grain of iridosmine which has been selected for the purpose, and soldered to the tip of the pen. These points are selected by first removing from the ore, by means of a magnet, the magnetic oxide of iron which always accompanies it, and then dissolving out, by means of acids, the other impurities which may be present; the ore is then washed with water, dried and sifted in order to remove the fine dust, and the sifted ore is then ready for the selection of points.

This is done by an operator, who rolls the grains of iridium around with a needle point, examining them under a magnifying glass, and selecting those which are solid, compact, and of the proper size and shape. These points are usually selected in the three grades, small, medium, and large, depending upon the size of the pen for which they are intended. The grain of iridium having been soldered to the end of the pen, it is sawed in two (making the two nibs of the pen), and ground into the proper shape.

Iridium is now being extensively used in alloying platinum, in the proportions of from 1 to 10 per cent., the object of the alloy being to raise the fusing point and increase the elasticity of the platinum. This alloy is made by fusing platinum with a Deville and Debray oxyhydrogen furnace, in a lime crucible, and adding the requisite amount of iridium. The mass is then removed from the furnace and forged, the fusing and forging being continued alternately until the alloy is homogeneous.

Holland's discovery has rendered the metal available in the arts, and many useful applications have already been made. In cases where hardness and non corrosibility are the properties desired, the presence of the phosphorus in the metal is not objectionable, but where the metal is to be subjected to great heat the phosphorus must be removed.

The methods for working the metal are in some respects novel and they will be briefly described. Iridium fused by Holland's process was first used for Mackinnon pen points, which are made as follows: The metal, after being fused, is removed from the furnace and poured between two plates of iron, which are brought suddenly together, on the plan of a closed mold with a hinge, so that as the metal cools it is subjected to pressure which closes the pores and makes a very compact casting. The slabs for the Mackinnon pen points are about one-thirty-second of an inch in thickness, and are broken up into small irregular pieces which are soldered on a strip of brass and ground down to a flat surface by means of a copper lap. The copper lap consists of a plate of copper about one-half inch in thickness and 8 inches in diameter, fixed on a spindle which is made to revolve from 800 to 1,000 revolutions per minute; the copper of which the lap is composed is wrought copper, well annealed, and consequently very soft. In order to grind with it, corundum or diamond dust is mixed with oil and applied to the flat surface of the lap by means of a flat steel instrument, called a "spud," upon which pressure is applied in order to force the corundum or diamond dust into the copper, thereby making a cutting surface. The iridium to be ground is held against this sharp surface of the lap, and the corundum or diamond dust gradually cuts the metal away. As the cutting material wears from the copper lap, another application of the corundum or diamond dust is made by means of the "spud" as described. This operation is continued until the grinding is complete. After the slabs are ground to a surface they are then drilled. In the drilling operation, the iridium is first countersunk by means of a diamond drill, consisting of an upright spindle suitably fixed in a frame so as to revolve freely; the bottom of the spindle holds a small rod of brass, to the lower end of which is set a white diamond splint. This drill is made to revolve about 900 revolutions per minute. The iridium is held up against the diamond with a light pressure, and the diamond gradually makes a conical hole or "countersink." After countersinking the iridium, it is finally pierced by means of a copper drill, which consists of a piece of soft copper wire, which is filed down to a point and set in a drill similar to that in which the diamond is placed, but this drill makes about 3,500 revolutions per minute. Corundum or diamond dust and oil are put into the countersink opening in the iridium, and then it is held up against the piece of revolving copper. The diamond dust or corundum, embedding itself in the copper, acts as a cutting surface, and finally accomplishes the drilling of the hole. The holes having been drilled in the pieces of iridium which were soldered to the brass, the brass is finally dissolved from the iridium by means of nitric acid; and then we have irregular-shaped pieces of iridium, pierced with holes. These pieces of iridium are then soldered in proper position to the end of the Mackinnon pen, fitting into the opening of which there is a valve consisting of an iridium-pointed wire. The iridium is then ground to the proper shape on the outside by means of a copper lap, consisting of three or more copper cylinders on a common spindle, making about 3,000 revolutions per minute.

The operation of sawing iridium is carried on by means of a copper disk, from 4 to 8 inches in diameter, made of soft thin sheet copper, held between two clamps, placed on a spindle revolving at the rate of about 2,500 revolutions per minute. This sheet of copper revolves in a box which contains corundum or diamond dust and cottonseed oil. The cottonseed oil with the cutting material adheres to the periphery of the saw, and as the saw comes in contact with a piece of iridium it gradually does the work. Cottonseed oil is preferred for this purpose to any other oil, on account of its viscosity.

The application of iridium for drawplates promises to be of great importance. There are at present, besides the iridium drawplate, the ordinary steel plate, which is used for drawing heavy wire, and the ruby plate, which is used in drawing gold and silver wires, where it is desirable to have them of uniform thickness. The iridium plate is made somewhat similar to the ruby plate, consisting of a piece of iridium which has been countersunk and drilled in the usual way to the size of the hole required, and set in a brass plate, where it is firmly held by a "bushing." This plate is now coming into use, and is rapidly taking the place of the ruby plate, being equal to the ruby in hardness and much more durable, since it is less liable to break or chip by rough handling or heating.

Iridium knives are made for fine scales and balances, the bearing edge of which consists of iridium, soldered firmly to a brass body. These are rapidly taking the place of the agate for fine-chemical balances, and there seems to be no reason why they should not have even a more extended use, since they are superior to the agate in that they take a finer edge and thereby make a more delicate balance, and are not so liable to crack or break. They are now being used altogether by Mr. Henry Troemner, of Philadelphia, the scale manufacturer, for the purpose of adjusting his weights for all of his scales.

Hypodermic needles for physicians' and surgeons' use are now made of gold and tipped with iridium, in place of the old steel pointed ones, which are liable to rust or corrode if not properly taken care of. The iridium being hard will take a good edge, and is not subject to corrosion, as is steel.

Styluses for manifold writing are also being made with iridium points, having decided advantages over either steel or agate. Iridium points are also being applied to surveyors' and engineers' instruments, and in all places, in fact, where hardness, durability, and non-corrosibility are required. For all the above uses the iridium, alloyed by fusion with phosphorus, is employed.

Some years ago experiments were made in order to apply this metal to the electric light. We found that an iridium electrode used upon the negative of an arc light would keep its shape and resist the heat, provided the positive carbon which was used with it was not allowed to strike or fall too heavily upon the iridium negative. Since the metal at a white heat becomes malleable, a continual pounding or striking would gradually beat the negative out of shape. The iridium negatives are made by setting a piece of dephosphorized iridium in the end of a brass or wrought-iron rod about 6 inches long and nine-sixteenths of an inch in diameter. The length of the iridium is about half an inch, ground conical in shape. It was found that the brass, being only half an inch from the arc, would resist the action of the heat; but, in some cases, where the lamp flamed, the brass was liable to undergo partial fusion; and in such cases it was found desirable to put a thimble or cap of platinum over the end of the brass and just below the iridium, the platinum thimble being about half an inch long.

One of the most important applications of iridium which has yet been made is to the electrical contact points of telegraphic apparatus. These contact points consist of pieces of copper wire tipped with dephosphorized iridium, which are set in the instrument just as platinum points are set. These contacts will outlive many platinum contacts, are not subject to oxidation or sticking as are the platinum ones, and all that is necessary in order to clean them when they become dirty is to pass over their surface an emery file or a piece of fine emery paper. These contacts have been thoroughly tested by various eminent electricians, and also by long continued use, and the advantages herein stated have been in every case fully demonstrated. The sesquioxide of iridium is used in porcelain painting to produce fine blacks and grays.

During the past three years we have been experimenting on methods for plating with iridium, and we have succeeded in obtaining a bright reguline deposit of iridium on base metals. There were many difficulties encountered in accomplishing this result, on account of the power of the metal to resist the action of the solutions. For this purpose the iridosmine is best decomposed by mixing it with common salt, and subjecting it to the action of dry chlorine gas at a low red heat. The mixture of iridosmine and salt is spread out in a thin layer in a shallow clay dish or pan and placed in a closed muffle, which is heated to a cherry red. The muffle is then sealed with clay or asbestus cement, so as to leave a small opening for a tube, through which the chlorine is passed into the muffle, and a similar opening at the opposite end for the exit of the gas. A steady flow of chlorine is maintained for about two hours, when the charge is removed and treated with water, which dissolves the iridium as a double chloride of iridium and sodium. From this solution the various well-known salts of iridium may be obtained with little difficulty. Several solutions have been employed with success in the electro-deposition of the metal, one frequently used being an aqueous solution of the double chloride of iridium and sodium, containing about 1 ounce of metal to the gallon of solution, to which a small quantity of sulphuric acid has been added. This solution slowly dissolves an anode composed of iridium which has been fused with phosphorus. An electro-deposit of iridium is extremely hard, resembling the massive metal in every respect. It is susceptible of a high polish, which is produced by "buffing." This new art promises to be of considerable commercial value.

Price of iridium.—Iridosmine as it comes from the mines, having been thoroughly washed and freed from "black sand," is worth from $2 to $5 an ounce, pure iridium being worth about $20 an ounce. Selected grains of iridosmine suitable for pen points have a market value of from $50 to $75 per ounce, according to size and quality.

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TIN.

BY W. P. BLAKE.

ORES OF TIN.

The chief ore of tin, and the only ore which has yet been found in any notable quantity in the United States, is the stannic oxide (SnO_2), known to mineralogists as cassiterite and among miners as "tinstone." It is a hard, heavy, crystalline, or massive substance without metallic appearance, usually of a brown to black color, and an adamantine or vitreous luster. The streak or powder is usually a light reddish brown. It is brittle and easily crushed, and when washed in a gold pan or in a sluice box with ordinary earth and minerals it settles to the bottom, and may be separated from them in the same way that gold is separated by washing. It is about as hard as quartz, and the specific gravity ranges from 6 to 7. It is commonly found in the older and crystalline rocks, especially in the coarsely crystalline granite rocks and dikes.

The ore known as "wood tin" differs from the crystalline cassiterite in its structure, being found in concentric layers or coats as if it had been deposited from solutions. When the spheroidal masses are broken they display a radiated, fibrous structure. It is found in the beds of streams, or in nodular masses in trachytic rocks, having apparently been formed in cavities throughout the mass. Cassiterite when pure contains from 90 to 95 per cent. of the oxide of tin, there usually being some iron, silica, and tantalic acid.

Cassiterite, as a metallurgical product, has been observed by Prof. R. H. Thurston, and is described by Prof. A. R. Leeds (*a*), of the Stevens Institute of Technology, as in needle-like crystals, not exceeding one-fourth of an inch in length and one two-hundred-and-fiftieth of an inch in thickness; luster adamantine, and of great brilliancy; color white, and transparent; hardness over 6, scratching glass; specific gravity, at 62° Fahr., by the bottle, 6.019, or less than the gravity of the natural cassiterite; infusible; insoluble in acids; chemically a stannic oxide containing a small amount of copper oxide. These crystals were formed upon the surface of a mass of bronze metal which had been poured out upon the brick floor of the foundry to cool. They appeared to grow out of the cooling mass. The alloy contained 42.05 per cent. of tin and 57.87 of copper.

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a "Copper-tin alloys," 1879, page 344.

A variety of cassiterite containing 9 per cent. of tantalic acid has been found in Finland, and has been described by Professor Nordenskjold under the name of "ainalite."

Stannite is a sulphide of tin and copper which occurs in Cornwall, and is known under the name of "bell metal ore" or stannine. It has not yet been observed in the United States.

The foregoing-named species are the chief ores of tin known. Tin oxide is, however, found in small quantities in many other minerals, especially in the tantalite group occurring in the granitic rocks and frequently closely associated with tin ores. These minerals are tantalite, columbite, tapiolite, hielmite, yttrotantalite, samarskite, æschynite, fergusonite, ferberite, and wolfram. In most of them the amount of tin is less than 1 per cent. In tantalite the amount has been found to vary from 1 to 9 per cent. A variety from Finland analyzed by Berzelius yielded 16.75 per cent. of tin oxide. Tantalite and columbite occur abundantly in the newly discovered tin region of Dakota, and occasionally in close association with the cassiterite. Large and well-formed crystals have been taken from the Etta tin vein. These crystals were imbedded in feldspar, and were not directly in contact with the tin-bearing albitic greisen, but near its margin between it and considerable masses of feldspar and quartz without tin. Columbite or tantalite, or both, are occasionally seen in smaller tabular crystals on the borders of the masses of greisen ore. The largest mass of this mineral yet known to mineralogical science was found at the Bob Ingersoll claim, in Dakota, and weighed over 1 ton. (*a*) It is stanniferous, and some small masses of cassiterite were found associated with it. A sample specimen of tantalite from the Etta mine analyzed by Professor Schaeffer, of Cornell University, contained 0.39 per cent. of stannic oxide. (*b*)

Metallic tin.—The occurrence of native metallic tin has been reported from Siberia by Hermann (*c*), and from Bolivia, but it is probably an artificial product. So also it is believed that the lumps of metallic tin in Cornwall found in the earth near the site of ancient tin-smelt-works are artificial in origin. Such masses in Cornwall are commonly known as "Jew's tin."

Stream tin.—The larger part of the tin of commerce is obtained from stream tin. In Cornwall, at first, the tin ore was obtained solely from the alluvions of the tin region; and even as late as 1876 it is reported that eight hundred persons were engaged in mining for stream tin on Red river. A considerable amount of ore is yet obtained from stream deposits rather than from veins; and at the present time the great production of New South Wales is from alluvial tin ores, such as were shown in profusion at the Centennial Exhibition, and again at Paris in 1878.

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a See "Columbite in the Black Hills of Dakota," by W. P. Blake, *American Journal of Science*, Vol. XXVIII., November, 1884.

b Transactions American Institute of Mining Engineers, February, 1884.

c *Jour. f. Prakt. Chem.*, Vol. XXXIII., page 300.

The Banca and Billiton tin is chiefly from alluvial ore, which is mined by Chinese labor.

According to Davies (cited from Van Diest), at the alluvial tin mines of Banca, a miner, with the aid of water, removes from 350 to 530 cubic feet of earth in nine hours, or by estimate 120,000 cubic feet yearly, with an average product, after smelting the black tin, of 1,200 pounds of metallic tin. In Australia, stream-tin miners are reported to handle 10 tons of earth daily.

Associates of tinstone in New South Wales.—In New South Wales, according to Liversidge (*a*), tinstone occurs in association with quartz, mica, orthoclase feldspar, molybdenite, fluorspar usually of pale shades of purple and green, a yellow steatitic mineral, garnet, beryl, and topaz. The matrix of the tinstone is in places composed solely of topaz; elsewhere it is malachite, copper and iron pyrites, mispickel, tourmaline, or schorl. Wolfram has not been seen in the same veins with the tin stone, but occurs in other veins almost in juxtaposition. Professor Liversidge also notes that nearly all the minerals found associated with tinstone in Cornwall, Germany, France, America, and elsewhere have been met with the mineral in New South Wales.

Percentage of tinstone or black tin in the ores of tin.—The amount of black tin or clean tin ore in the bulk of tin stuff raised from the mines varies greatly in different tin regions and at different lodes or mines in the same region, but it rarely exceeds 3 per cent. of the mass, and is generally less than 2 per cent., or 40 pounds in a ton of 2,000 pounds. In Cornwall, for example, where the statistics of mining are carefully kept by the Government, it is found that the average yield of black tin in the whole mass of tin ore as mined and stamped, or prepared for dressing, is not over 45 pounds to the long ton, or 1.95 per cent. At Altenberg, in Saxony, the smelting ore, or black tin, is not more than 0.5 to 0.3 per cent. of the whole mass. In the Schlackenwald tin-mining district near Carlsbad, in Northwestern Bohemia, tin occurs in greisen rock exactly resembling the rocks at Zinnwald, and occurring in two small conical masses of granite. One of them was worked in ancient times. The other has been continuously mined for several centuries. In the year 1355 there was a considerable production of tin from this locality, and for a long time Schönfeld and Graupen were the only productive tin mines of central Europe. (*b*) In 1550 the production was 800 tons from Schönfeld and Schlackenwald, and in 1580 Schlackenwald alone yielded from 300 to 400 tons. The rock at that time yielded 0.5 per cent. of tin. According to Reyer (*c*) the percentage gradually decreased from 0.5 in 1570 to 0.2 to 0.4 in 1850. It is stated that about 50,000 tons of tin were produced in this district during the sixteenth

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[a] "The Minerals of New South Wales," by Archibald Liversidge, F. R. S., page 40 [102]. Sydney, 1883.

[b] Phillips, "Ore Deposits," page 321.

[c] E. Reyer, "Zinn," 1881, page 74.

century; and as 300 tons of rock yielded only 1 ton of tin, 15,000,000 tons, or about 7,000,000 cubic yards, must have been worked. In 1881 the production of tin in Bohemia and in the whole of Austria was from two mines and amounted to 1,051 tons of tin ore.

According to Phillips and Darlington(*a*) the quantity of black tin did not exceed 17½ pounds per ton of ore at one of the largest mines in West Cornwall in the year 1855. This upon the long ton of 2,240 pounds is equivalent to 0.77 per cent. The same authorities, describing the effectiveness of the ordinary stamp mill in crushing tin ores, give the following figures:

The average number of stamps in use at the Polberro mines was 70, and the quantity crushed in the course of five years was 106,249 tons. This quantity averaged 20.1 pounds of merchantable black tin (per ton of 2,240 pounds), equivalent to 0.89 per cent. The profit per stamp amounted to £210 for the whole period or £42 per stamp per annum. The average price of black tin was £63 2*s.* 4*d.* per ton.

The general average yield of black tin of six large mines upon the great flat lode of Redruth, Cornwall, in 1876 was 2.21 per cent., ranging from 1.47 to 3.02, as shown by the following table, which gives also the output of the mines for that year and the number of pounds of clean tinstone obtained:

Quantity of clean tin ore or black tin in the tin stuff raised from six mines in Cornwall in the year 1876.

Mines.	Tin stuff.	Clean tin ore.	Per cent.
	Longtons.	*Longtons.*	
Wheal Uny	17, 702	349	1. 97
South Carn Brea	2, 040	30	1. 47
West Basset	29, 144	618	2. 10
West Wheal Frances	6, 652	123	1. 80
South Condurrow	19, 414	588	3. 02
Wheal Grenville	8, 500	138	1. 62
	83, 452	1, 846	2.21

ORIGIN OF TIN ORE.

Daubrée in 1841 regarded tin ore as formed by the sublimation of the fluoride of tin, which underwent decomposition by the agency of water and the adjacent rocks, causing the deposition of oxide of tin. (*b*) He cites the presence generally as associates of tinstone of minerals containing fluorine, such as fluorspar, mica, tourmaline, and topaz, as favoring this view. Von Cotta says that it is the almost universal observation on the continent of Europe that the tin deposits occur mostly with granitic rocks. This is seen in the Erzgebirge; at Schlackenwald, in Bohemia; in Brittany, and elsewhere. Hence, and for other reasons, he concludes that generally tin ore originates in the older crystalline

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a "Records of Mining and Metallurgy," page 140.

b *Annales des Mines, Tome* XX., 1841.

rocks rich in silica and deep-seated in origin, and in so far of plutonic origin; rocks which have solidified at great depths and consequently under great pressure. This conviction is repeatedly expressed in his treatise on ore deposits. (*a*) He notes, however, the exception of the tin ores of the veins in Cornwall, which, according to the observations of De la Beche, are more recent than the Devonian and Carboniferous formations. Von Cotta points out that tin ore is never found in limestone or dolomite.

Dr. Le Neve Foster, of the geological survey of Great Britain, from his extensive and careful studies of the Cornwall veins, regards the tinstone of Cornwall, at least, as the result of the infiltration of stanniferous solutions depositing the tinstone in granite adjacent to fissures, partly by replacement and alteration of the granite.

In a series of articles upon the tin ores of Cornwall (*b*) Mr. J. H. Collins shows that the associated minerals are nearly the same as found with the ore in other tin regions. Tourmaline is a common associate and is regarded as contemporaneous in its origin, as well as quartz, mica, and feldspar. He concludes that the tin ores have been deposited in their present positions from stanniferous solutions of aqueous origin, and that the tin was originally derived from the surrounding rock and afterwards deposited by thermal waters in fissures.

In the numerous tin veins and granitic dikes bearing tinstone in the Dakota tin region all the phenomena go to show that the minerals of the dikes, the quartz, feldspar, mica, spodumene, beryl, columbite, tantalite, and other associates of the cassiterite, were contemporaneous in origin. All these minerals appear to have crystallized out of a semifluid or pasty magma in which the elements were free to arrange themselves from one side of the dike to the other, and to separate out by slow crystallization. There is a banded arrangement, sometimes very distinct, and again obscure; but different from the banded structure seen in fissure veins, where there appears to have been an open fissure subsequently filled gradually by the flow of water depositing layer after layer upon each side of the fissure until it became filled. In the dikes the rude structure seems rather to be due to the crystallization of the magma which filled the space between the walls, the difference of structure of the portion next to the walls being the result possibly of difference of pressure or temperature, or the different temperature or conditions governing the formation of one compound after another. Thus, in the great dike or injected mass of the Etta mine, mica is generally found next to the walls, so also at the Ingersoll, while feldspar and quartz fill the center; but this central mass is penetrated in every direction by the enormous crystals of spodumene, the cassiterite being disseminated in bunches, but particularly in the included masses of albitic greisen which seem to have filled the spaces left after the other

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[a] Primo's translation, pages 422, 423, 485, 507, 522, 535, and 541.

[b] *Mineralogical Magazine*, Vol. V., page 121.

minerals had assumed their form. The evidence is conclusive that the cassiterite is not the result of later infiltration, but that it was formed with the other constituent minerals of the mass. It exists in the unchanged rock as one of the constituent minerals of the rock.

The Government geologist of Queensland states that there is an intimate connection between the tin deposits of that region and metaphorphosed igneous dikes. These dikes are said to consist mainly of quartzose chlorite, and occasionaly of quartzose serpentine. They appear to have undergone a gradual process of metamorphism. The tin ore occurs irregularly among the joint planes of the dikes. It is regarded as possible that the tin oxide was originally disseminated in the mass of the dike, and that it was afterwards dissolved out and redeposited—concentrated—in the open joint planes of the rock. The possible deposition of tin ore in the fissure of the dike by ascending mineral solutions is also considered. (*a*)

The wood tin ore of Durango, Mexico, is said to occur in cavities in a mass of porphyry rock from which it is gradually liberated by disintegration.

Tin oxide in fossil bones.—In some of the stream deposits of tin ore in Cornwall fragments of deers' antlers have been found containing considerable tin oxide, which appears to have penetrated and replaced portions of the bone. Specimens are to be seen in the British museum and in the Penzance museum. An analysis of one of the specimens showed the presence of 2.6 per cent. of tin oxide, and under the microscope the oxide of tin and oxide of iron could be seen in the interior of the mass. The question arises whether or not extremely small grains or fragments of stream tin, even as fine as dust or powder, may not have been mechanically carried into the pores of the bone.

TIN ORE IN THE NEW ENGLAND STATES.

New Hampshire and Massachusetts.—The discovery of a few crystals of tin ore at Goshen and at Beverly, Massachusetts, has already been mentioned. The localities have no commercial importance and have not yielded any tin. The discovery of tin ore in place in veins at Jackson, New Hampshire, was made by Dr. Jackson in September, 1840. The veins he describes are small; from half an inch wide to 8 inches in the widest part. The tin ore is in the form of crystallized cassiterite, and is associated with copper pyrites and arsenical pyrites, with some fluorspar and phosphate of iron. These veins traverse mica-slate and granite in the vicinity of a trap dike. Dr. Jackson regarded them as having been formed by the sublimation of the tin ore, and its deposition with the other minerals on the sides of crevices in the granite and mica-slate, the minerals filling the space from the sides to the center, where there is a thin layer of quartz separating the vein into two equal parts. He cites the views of Daubrée respecting the origin of tin ore.

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a Abstract in *Engineering and Mining Journal,* May 10, 1884.

Maine.—Tin ore has also been observed at several localities in the granitic rocks of Maine. Dr. Jackson in 1869 read a notice of its occurrence in the town of Winslow. (*a*) It occurs more sparingly in the same State at Paris and Hebron, and at Goshen in Massachusetts, also at Haddam in Connecticut; and at all of these localities, except perhaps at Winslow, Maine, it is regarded as a mineralogical curiosity.

According to Dr. Hunt (*b*) the tin ore at Paris and Hebron occurs with orthoclase, quartz, tourmaline, and beryl in concretionary granite veins, which cut through the micaceous gneisses of the White Mountain series of rocks. At Winslow the veins traverse an impure gray micaceous limestone subordinate to the same gneissic series. The veins are small but numerous, and are generally interlaminated with the rock, though occasionally cutting across it for a short distance. The cassiterite is accompanied by fluorspar, a silvery white mica, and a little mispickel.

The discovery of tin ore at Winslow, Maine, did not appear to be of sufficient importance to justify the expectation of profitable mining, but some ten years later, or about the year 1880, other veins were found and a company was organized to work them under the title of the Maine Tin Mining Company, with its office at Bangor. The property was examined and described by Prof. C. H. Hitchcock, of Hanover, and by Prof. Forest Shepherd, of Norwich. The ore occurs in small but regular veins, beautifully formed, and traversing a very hard and compact siliceous and micaceous schist, and near a layer of quartzite. The mica-schist is pyritiferous and there is no separation or clay between the sides of the veins and the country rock. The structure is shown by the drawing, made of full size from a hand specimen, showing the breadth of the vein with a portion of the adjoining mica-schist on each side. The vein filling consists of white mica or lepidolite on each wall; then a medial line, or mass, of fluorspar, in which the crystals of cassiterite are irregularly dispersed. In some parts of the vein there are indications of a second or parallel layer of tinstone and fluorspar in a siliceous band, apparently a second filling of the fissure. Other minerals, such

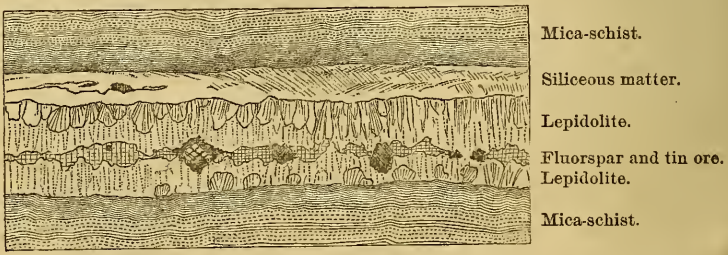

FIG. 7.—Occurrence of tin ore at Winslow, Maine.

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a Proceedings of the Boston Society of Natural History, Vol. XII., page 267, 1869.
b Transactions American Institute of Mining Engineers, Vol. I., page 373.

as mispickel and beryl, are named as associated, and it is said that there are at least twelve of the small veins, from one-half of an inch to 3 inches in width, traversing the mica-schist within a breadth of 30 feet. Geologically, Professor Hitchcock regards the rock formations as the equivalents of that which carries those interesting fossils *Nereites*, *Myriarites*, etc., which are really trails of creatures like annelids. Lithologically, the rocks are slates with a few limestones and many quartzite seams. The formation compares best with the Coos group cf New Hampshire and the calciferous mica-schist of eastern Vermont, which carries the copper veins or masses of East Strafford and Corinth.

A shaft has been sunk on this property to a depth of 100 feet, and a cross-cut has been made for 20 feet at the bottom and one also at 70 feet from the surface. The veins which are cut by these openings appear to be dipping toward each other at the rate of 1 foot in every 20 feet of depth, or 5 feet in the 100 feet. Four of the veins have already become merged in two. The tin oxide crystals are found here and there in the vein, being sometimes absent and again appearing in numbers. Some samples of metallic tin have been reduced from the ore and some foil has been rolled out from it. The quality appears to be satisfactory. The company proposes to sink the shaft to a depth of 200 to 250 feet before commencing to drive upon the veins.

TIN ORE LOCALITIES IN THE MIDDLE AND SOUTHERN STATES.

New York and New Jersey.—Small quantities of tin are said to have been detected by chemists in the magnetic iron ores of the highlands of New York and New Jersey.

Virginia.—Tin ore has for a long time been known to occur sparingly in some of the auriferous gravel drifts of the gold-bearing belt of rocks, but it has not been found in quantity sufficient to justify the hope of mining it profitably until the past year. It is now reported from Rockbridge and Nelson counties, and in West Virginia from Mason and Cabell counties.

In Rockbridge county the ore is found in the crystalline rocks of the Blue Ridge on a branch of Irish creek, 7 or 8 miles from Vesuvius station on the Shenandoah Valley railroad. Two openings had been made before October, 1883. The locality is described by Messrs. McCreath and Platt.(*a*) Opening No. 1 shows the crystalline rocks standing nearly vertical and consisting for the most part of quartz, feldspar (orthoclase and albite), hornblende, and at a few points mica-schist. The tin-bearing vein apparently cuts across the rock for 36 feet and then follows the bedding. This vein is made up of white quartz with tin ore, but the thickness is not stated. The largest piece of rich ore was not over 2 inches in thickness, and much was not over 1 inch. A 7-inch vein had been reported in the vicinity. The samples assayed showed

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a Communication to the president of the Shenandoah Valley railroad; *Bulletin Iron and Steel Association*, November 7, 1883, page 207.

an average of 31.60 per cent. Opening No. 2 shows only some loose float specimens of ore.

The Nelson county tin district adjoins that of Rockbridge. Veins of good size are reported, and they are said to have been traced for a great distance on the surface. According to Professor Campbell, of the Washington and Lee University, Lexington, Virginia., the ore is found on Painter Mountain branch of Irish creek, about 1¼ miles from the Nelson county line. It is in a vein running east and west, several inches thick, and traverses a rock consisting principally of large crystals of quartz and feldspar with some mica.

Another writer(*a*) gives an extended description of the tin district and mentions particularly several tracts of land upon which tin-bearing veins have been found. Amongst these are the Cash tract, the Grant tract at Mount Maria, the Big Hill, the Clarke tract, and the Robertson tract. More or less prospecting has been done over a distance of 5 or 6 miles southwesterly from these localities, but little work appears to have been done. A company has been organized to work some of these veins under the incorporate title of the Virginia Tin Mining and Manufacturing Company, with Edgar Whitehead of Amherst Court House, Virginia, president, and R. M. Cox, secretary. The work of sinking a shaft commenced November 17, 1884. According to Prof. F. A. Massie(*b*), of the University of Virginia, the Martha Cash tin mines are situated at an elevation of about 2,700 feet on the northwestern slope of the Blue Ridge, 22 miles east of Lexington, the county seat of Rockbridge county. The veins are in a granitic rock, consisting chiefly of coarse-grained aggregates of feldspar, hornblende, and quartz. This prevailing granitic rock is varied by frequent occurrences of lenticular bedded masses of the rock known as unakyte—a highly crystalline coarse-grained compound of microcline, quartz, and epidote; and again by dikes of trap. Tin ore of varying quality has been found over an area of between 2 and 3 miles. The main lode extends in the general direction of the mountains and rock formations and dips to the southeast. It has "feeders" or "offshoots" accompanied by trap dikes. It is apparently made up of several parallel veins with an average width together of perhaps 100 feet and traceable on the surface. The tin ore is in the form of cassiterite or black tin in sheets, strings, and nodular masses in the gangue of veins. The color is from light yellowish brown to dark brown, and the ore is free from injurious minerals. 'The workable ore so far as shown exists practically altogether in lumps and veins clearly definable, the inclosing wall being impregnated to but a slight extent and in itself, alone, is too low in percentage to justify working." The gangue is permeated with muscovite mica. The associate minerals, so far discovered, are

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a Dr. William Robertson, in the London *Mining Journal*, October 18, 1884.

b "Report on the Martha Cash Tin Mines" in the prospectus of the Virginia Tin Mining and Manufacturing Company, 1885.

wolfram, mispickel, and beryl. Wolframite occurs in some of the veins with the tin ore. The mispickel contains more or less gold. The following descriptions of the two principal openings showing tin ore are condensed from the report cited. Beginning on the hill above the creek "No. 2" is an open cut 100 feet long, north and south, 4 feet wide, and 10 feet at its deepest. In the middle there is an exposed ledge of ore and veinstone 4 feet thick, consisting of ferruginous and micaceous quartz seamed with strings, lumps, and masses of cassiterite throughout the mass. Selected pieces of the tinstone yielded more than 70 per cent. metallic tin. "The entire veinstone shows a slight impregnation of ore, but as above remarked as true of all the veins at their present development, of too low a percentage to alone pay for working." Opening "No. 1" is a quarry 60 feet long, 8 feet to 10 feet wide, in an east and west direction, with two trenches. In one of these there is a continuous and well-defined vertical vein of crystalline cassiterite averaging 1 inch in thickness. About a ton of this ore has been removed and is of the highest grade, yielding on assay 75 per cent. of metallic tin. "The cuts on the southern flank are impregnated to a slight but not workable extent." Specimens from these localities were exhibited in the Virginia mineral collection at New Orleans.

North Carolina.—Tin ore was discovered in 1883 in Cleveland county near King's Mountain by a young man named Claywell, attending school, whose interest in minerals had been aroused by exploring in company with Professor Humphrey. Specimens were exhibited at the Mechanics' fair in Boston in 1883, in the North Carolina State exhibit, under the charge of Dr. Dabney. The outcrop is said to be traceable about 1½ miles. It consists of a more or less irregular and broken vein, or a series of small veins, traversing a decomposed mica-slate. One vein was found nearly 3 feet wide. The ridge penetrated by these veins is about 50 yards wide. The assays of samples show a high percentage of tin.

Georgia.—Minute quantities of tin ore were found by W. P. Blake in some of the residues of gold washing operations in Lumpkin county, Georgia.

Alabama.—Prof. C. U. Shepard(*a*) has noted the occurrence of cassiterite in Coosa county and its occurrence in Clay county, near Ashland, has been described by Mr. G. W. Gesner, of New York City, and also in the preceding volume of this series.(*b*) This locality has been worked by a company organized and managed by Mr. Gesner. He describes the formation as a tin-bearing gneiss, in which the ore is disseminated both in grains and in pebble-like masses over a breadth of from 10 to 20 feet, associated with massive white quartz and limonite. There are six nearly vertical belts of stanniferous gneiss in a breadth of 800 feet. The amount of tin stuff in the rock is considered to range from a trace

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a American Journal of Science, third series, Vol. XX., page 56, 1880.

b "Mineral Resources of the United States, 1882," page 434.

up to 1 or 2 per cent. These deposits are known as the Broad Arrow mines, and considerable development work has been done in the form of quarries and cuts in the hillside. Regular work commenced March 1, 1883, and a stamp mill and concentrating works were started March 20. The tin ore was found to be so very fine that it could not be successfully concentrated by the machines ordinarily in use for the purpose. In December, 1884, a Frue vanner was set up and operated with gratifying results, and it is now proposed with its aid to test the various belts or layers of tin-bearing gneiss so as to determine what portions can be worked with commercial results. Eleven men were employed on the mine and works in the year 1883 and ten men in the year 1884. There has not been up to this time any tin produced in a commercial way, but a bar of tin from this locality was exhibited in New York in 1883. Mr. Gesner, under whose direction the work has been prosecuted from the beginning, states that these tin-bearing rocks of Alabama begin at the granite formation in Cleburne county, and extending in a southwesterly direction pass through Randolph and Clay counties into Coosa county, where they disappear under more recent deposits. The belt is nearly 100 miles in length and is in the center of the gold-bearing district.

Reported occurrence in Texas.—The tin ore reported to have been found near Fort McKavett, in Texas, has been shown by Professor Schaeffer, of Cornell University, to be brown garnet only, a mineral frequently mistaken for tin ore by prospectors not familiar with tinstone.

Missouri.—Tin has been frequently reported from Missouri, but it is doubtful whether it occurs there in any considerable quantity. Some specimens said to have been found there are regarded as from Cornwall, England. Dr. Hunt mentions a curious replacement of titanic acid by stannic acid in sphene or some similar mineral at a locality in Missouri.

Reported at Lake Superior.—A few years ago tin was reported to have been found in large quantities at the head of Lake Superior, but examination by competent experts proved that the representations were false, and the swindle was exposed. A barren vein had been picked out and the space between the walls was refilled with artificial stone mixed with rich specimens and washed tin ore. The brook below was also charged with foreign ore. Samples were then taken, with apparent innocence, to assayers as iron ore.

TIN ORE IN THE BLACK HILLS OF DAKOTA.

The discovery of tin ore at the Etta mine.—In June, 1883, Maj. A. J. Simmons, of Rapid City, forwarded to General Gashwiler, of San Francisco, a box of specimens of a very heavy dark-colored ore, which on examination proved to be cassiterite in a massive form, assaying 40 per cent. in metallic tin. A short preliminary notice of the discovery and of the associated minerals and the geological formation was published in the *American Journal of Science* for the month of September, 1883.(*a*)

The discovery is in the central portion of the Black Hills, in Pennington county, about 20 miles southwest of Rapid City, 2 miles from Harney City, and a few miles east of Harney Peak, near the backbone or dividing range of the region. It is upon a claim known as the Etta, on an isolated conical granitic hill rising about 250 feet above the surrounding valley, and at an elevation of about 4,500 feet above the sea. This hill is in the midst of a very rugged country, which is drained by the tributaries of Battle creek, one of the largest streams of the Hills. But although the peaks and ridges are rugged, the intervening spaces are comparatively smooth and open, and permit the construction of roads at small expense. The wagon road from Harney extends up the creek to the cabins on the claim, at the foot of the peak of the mountain. There is a thick growth of pine timber over the whole region, and there is an abundance of pure water in springs and in running brooks. The rocks, the vegetation of the valleys, and the climate all remind one of the mountainous parts of northern New England.

Geological horizon.—The Black Hills, rising like an island in the broad expanse of the plains, are everywhere surrounded by the outcropping edges of the sedimentary formations, from the base of the Silurian upward to the Tertiary, so far as they exist in the far West. These formations dip gently away on all sides from the central nucleus of more ancient rocks, which rise up in a multitude of irregular peaks and broken ridges with a general northerly and southerly trend. These rocks consist chiefly of fine-grained mica-schist and micaceous sandstones, traversed by veins of quartz, which are often auriferous, although the quartz has that peculiar glassy, barren look which is seen in the quartz veins of New England, and appears utterly unpromising for the precious metal. The slates in some portions are highly charged with small brown garnets, forming perhaps 20 per cent. of the mass, so that the rocks may be said to be garnet-slates rather than mica-slates. There is also an abundant development of staurolites and of staurolite slate. Lithologically considered, these rocks remind the geologist of portions of the White Mountain series of formations, and are probably the equivalents of the Coos group, as described by Prof. C. H. Hitchcock, of New Hampshire. By the geologists Newton and Jenney, in their report on the Black Hills, the mica-schists of the whole region are referred to the Huronian period; and in the preliminary notice of the discovery of tin ore in Dakota this view was accepted. Further examination of the rocks and a consideration of the subject require a modification of this opinion, and a reference of the rocks—at least those which abound in garnets and staurolites—to a later period. There is a sufficient

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(*a*) See also the columns of the *Engineering and Mining Journal*, September 8, 1883; and a reprint entitled "The Discovery of Tin Ore in the Black Hills of Dakota," etc., by W. P. Blake; pamphlet, 14 pp., 1883.

breadth of formation, however, to include all the formations—the Huronian as well as formations referable to the Coos group and later rocks. In addition to the micaceous and garnetiferous slates, there is a large development of ancient sandstones, with very regular and even stratification and in thick beds, attaining together a thickness in some places of 200 feet or more. No limestone beds have been observed in the tin region, and the magnesian rocks appear to be absent. Toward the central portion of this area of mica-schists granitic intrusions make their appearance and rise in rugged peaks or long dikes in the midst of the slates. Approaching the dominating ridges of Harney peak, the stratified slates and sandstones give place to an irregular network of granitic dikes, and granite rock is the chief formation. Slate is found, however, at the very summit of Harney peak, capped by a remnant of a dike or granitic bed, which there has a horizontal position.

The granitic masses, especially those on the confines of the granitic area, are remarkable for the extreme coarseness of their crystallization, the constituent minerals being unusually large and separately segregated. Large masses of pure quartz are found in one place and masses of feldspar in another; and the mica is often accumulated together, instead of being regularly disseminated through the mass. It also occurs in large masses or crystals, affording sheets broad enough for cutting into commercial sizes. This occurrence of mica has led to considerable prospecting of the region for mica, and numerous claims have been located and worked. The quarrying for mica on the Etta claim brought the heavy black tin ore to notice; for Tin mountain, where it occurs, is one of these intruded masses of coarse granite. The surrounding schists are not greatly metamorphosed from their original condition, and the transition from schist to coarse granite is sudden. These micaceous and garnetiferous schists of the Black Hills in the region of Harney City and the Etta mine have been subjected to more folding, compression, and uplift than the same formations nearer the axis of the range. In the lower hills the troughs of the strata, or the longer axes of these folds and wrinkles, instead of being approximately horizontal, as is usual, are on the contrary nearly vertical, or are highly inclined. The troughs of the strata thus stand nearly on end. It results from this folding and upheaval that the structure or grain of the rocks, so far as it is imparted by the folding, is nearly vertical, and at the same time is convoluted; and in consequence the formations, in wearing away by erosion and disintegration and decay, are left with a peculiarly uneven surface, presenting a succession of pointed hills and peaks rather than a series of nearly parallel ridges. This folded structure is the basis of the peculiar topography of the country; it is the cause of it. Even the quartz veins partake of the folding, as may be seen by their serpent-like outcrops, and become columnar masses extending to great depths, while their surface extension appears to be comparatively limited. This is true also of the granitic intrusions. They appear at the Etta mine and in its vicinity as columnar bunches rather than sheet-like veins. The structure indicates a double folding and uplift, first horizontally, then vertically. These phenomena, although apparently purely scientific in interest rather than of any "practical" significance or importance, have nevertheless, in this case particularly, a direct economic and money value. They go to show that the veins which, with their schistose walls, are so crumpled up have a great downward extension. They probably extend much deeper than their lateral extension would indicate. In fact this is not merely a deduction from the structural form, but it is made evident to the eye by a close inspection of any of the outcrops of the schists in which quartz veins occur. If a fragment of quartz is broken out from such outcrops its form is found to be columnar and approximately cylindrical. So also the slates break out in columnar masses and not in flat sheets.

The gold-bearing rocks of the Deadwood region have a similar structure, and the paying portions are controlled by or follow the pitch of the folds, which pitch or inclination is, however, not so steep as in the tin region. The granite intrusions of other parts of the Harney Peak range are more regular and tabular, like regular dikes or veins.

Development work at the Etta mine—In 1884 the Etta tin mine, together with the adjoining claim known as the Ferguson and several placer locations, water rights, etc., became the property of a company organized in New York called the Harney Peak Tin Mining, Milling and Manufacturing Company. This company has expended a large amount of money in opening and prospecting the Etta. Tunnels have been run and open cuts have been made at various places so as to show the form and extent of the ore-bearing ground. In these operations it is estimated that over 1,000 tons of ore have been thrown out. There are seven or eight large square piles of tin-bearing greisen of good quality ready for milling, besides a considerable amount of ore left mingled with the waste in the dumps.

Greisen rock carrying tin was cut in the west tunnel about 50 feet below the top of the hill, and some fine specimens of massive tin ore were found in the north cut, some of which were sent to New York and also to the New Orleans Exhibition.

A lower tunnel, projected to cut the vein at a depth of 175 feet below the top of the hill has recently penetrated it at a point about 200 feet from the entrance of the tunnel and directly under or a little west of the point at which the vein was cut by the upper tunnel. This sustains the opinion based on the surface indications that the vein would prove to be a columnar mass, and it strengthens the belief that the mass has a great downward extension. At the intersection of this lower tunnel with the vein a distinctly formed selvage of clay was found between the vein and the country rock. There was also a considerable flow of water from the vein after this selvage of clay was penetrated.

Concentric structure of the Etta vein.—The Etta tin-bearing vein, measuring over its outcrop about 150 by 200 feet, has a rudely concentric structure or arrangement of the minerals which compose it. The outer portions next to the micaceous sandstone of the country rock consist of both dark-colored and light-colored mica, in large quantities. The dark-colored mica forms the outer envelope, and is apparently formed in the granular sandstone. The tunnels and cuts made into the vein from the side of the hill all show this mica before the ore is reached. It varies in thickness from a few feet to 2 or 3 yards. At some points there is a development of light-colored mica, ordinary muscovite, in sheets several inches broad, large enough to be commercially valuable. Passing through this zone or belt of mica, the tunnels usually enter a mixture of quartz, spodumene crystals, and greisen rock, carrying the tin ore in black kernels and grains. The central portion consists largely of massive quartz and feldspar. The general form and arrangement are shown by the annexed illustration, reduced from the map made for the Harney Peak Tin Mining Company by Prof. Gilbert E. Bailey, the superintendent. From the nature of the drawing it exhibits a greater degree of regularity and sharper definition than can be seen upon the surface of the hill, and the indication of the belt of greisen rock is to be

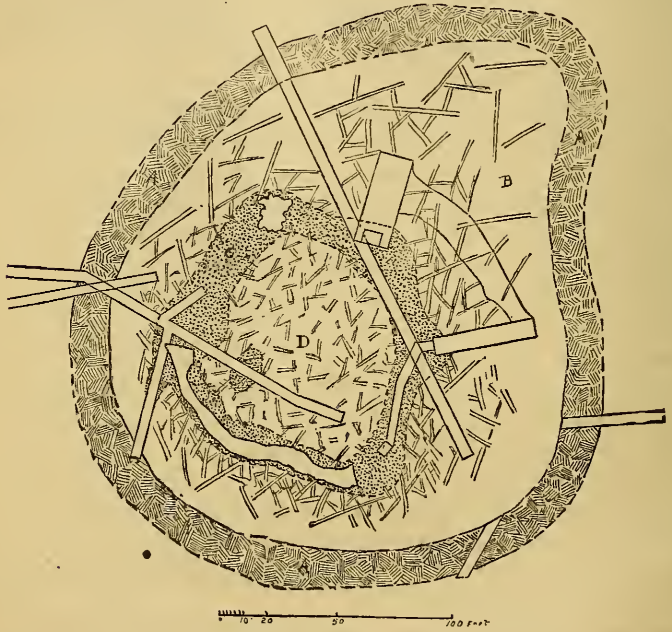

Fig. 8.—Horizontal section of the Etta lode.

A. Band or zone of biotite and muscovite mica.
B. Crystals of spodumene, with greisen carrying tinstone.
C. Greisen carrying tinstone.
D. Central core of quartz and feldspar.

regarded as showing the position of the irregular masses of greisen rather than their form. They are extremely irregular, and they fill the spaces between the immense interlacing crystals of spodumene.

The places at which the various bands of minerals have been cut and exposed by openings are shown by the lines indicating open cuts and tunnels. The central portion is chiefly quartz and feldspar. There is also toward the outer portions of the mass a narrow belt, but irregular and intermittent, of phosphatic compounds forming a layer of phosphatic minerals, allied to triphyllite and heterosite, on the borders of the ore.

Since the discovery of tin ore at the Etta it has been found in other similar granitic outcrops, especially at the Bob Ingersoll claim and in the Monarch claim, each of which has been worked for mica, and also on the western side of the Harney range, and in Wyoming.

The mineralogy of these granitic masses is extremely interesting. At the Etta claim the massive tin ore was found near the top of the hill, in the excavation made for mica. It was in close association with quartz, feldspar (both orthoclase and albite), and a remarkably large variety of spodumene. There is, in addition, the granular form of the ore, in small crystalline grains, disseminated in the massive micaceous albite rock of greisen, which penetrates or is inclosed in the coarse granite irregularly.

Varieties of ore at the Etta claim.—There are thus two distinct forms of occurrence of the tin ore at the Etta mine: (1) Massive, in bunches, with spodumene, feldspar, and quartz; (2) granular, disseminated in a micaceous aggregate or greisen.

In the massive form the ore is associated chiefly with the spodumene. It is not only in direct contact with the spodumene, but in some places actually penetrates it, so that it appears to partly replace portions of the crystals. A specimen, weighing 1½ pounds, is two-thirds tinstone and the remainder spodumene. Another specimen exhibits the tinstone traversing the spodumene irregularly. Besides this penetration and replacement of spodumene by massive tin ore, it is not unusual, on cleaving a mass of spodumene, to find small flattened grains of cassiterite in the body of the crystal, often mere stains or patches on the cleavage surfaces. In this form it has the appearance of being a secondary deposition. Later developments show that the impregnation of the spodumene is not general, but is confined to the neighborhood of the bunches of massive cassiterite, which also penetrate the masses of quartz and of feldspar in such a manner as to indicate their contemporaneous origin.

Of the massive form of the ore about one ton of fragments was taken out in a short time. Some of the heavier masses weighed from 50 to 60 pounds. Lumps weighing 3 and 4 pounds were common. Most of the larger masses were broken by the miners. They were in fact too heavy to handle with ease. The specific gravity of selected fragments of this massive ore is 6.753. The streak is brownish gray. Some of the masses have green films or crusts on the surface, derived from the decomposition of some small grains of vitreous copper disseminated at one side of the massive ore. Some grains of arsenical pyrites have also been observed, but the quantity is extremely small. A peculiar hydrous oxide of tin occurs also near to the surface. It is apparently derived from the alteration or decomposition of the cassiterite. Columbite occurs also in masses and crystals of unusual size and beauty, and is found chiefly in the massive albite near its contact with spodumene. It is also found in broken fragments associated with the ore which has disintegrated from the rock, and which can be gathered from the surface by sluicing.

The spodumene occurs in huge crystals, far larger than any heretofore observed in any part of the world. They are many feet in length, and range from a few inches to 2, 3, and 4 feet in diameter. They stand in the midst of the feldspar and quartz in all directions, and cross and intersect each other at all angles. In one of the open cuts these crystals standing in the sides look like huge timbers set up to sustain the rocks. One crystal, which is nearly horizontal in its position, shows in the side of a drift for 36 feet without a break or deflection. The association of cassiterite with spodumene has been observed at Hill City and in several places in Maine.

Greisen rock carrying tinstone.—The granular or disseminated form of the tin ore appears to be the most abundant and constant. The micaceous aggregate in which it occurs consists of a mixture of small scales of mica and of albite, also in small or granular masses, or in plates radially aggregated. The dominant mineral is the mica, which is in crystalline plates seldom over half an inch across, but is without well-defined lateral planes. Its color is light greenish yellow. It is dense and hard, and some of the plates are sufficiently clear and transparent to permit of the measurement of the inclination of the optical axes, which was found to be, in air, from 75° 30′ to 76°. This high angle and the association of the mineral with tin ore and spodumene suggested the reference of the mica to lepidolite; but no satisfactory reactions for lithia can be obtained with the blowpipe. The weathered surfaces resemble those of the Zinnwald lepidolite, being dark colored and showing the edges of the crystals. Beautiful rose-colored lepidolite occurs, however, at the Ingersoll location, a few miles distant. The mass of greisen ore weathers well, and stands out above the other minerals. It crops out boldly at intervals over the whole top of the mountain for a breadth of 100 feet or more, and penetrates the coarsely crystalline mass formed of orthoclase feldspar, quartz, and spodumene, as if it had a separate and later origin, either by intrusion or segregation. The grains of tin ore often occur irregularly disseminated, sometimes at the base of an aggregation of mica crystals at the junction with the white spar, and again it is found more sparingly in the midst of the mica crystals in thin flattened transparent plates, recalling to mind the inclusion of plates of tourmaline in the sheets of muscovite mica of New Hampshire and other localities. When in such thin plates, the color by transmitted light is a light clove brown. Such small crystals are easily detached by splitting the mica plates.

The mineralization of this albitic greisen with tin ore is general throughout the mass; at least, the tin ore can be found wherever the micaceous aggregate crops out, as is shown by breaking off masses from projecting points. But where large blocks of rock have been blasted out, as in the open cut, and fresh surfaces are exposed, the amount of ore in different parts of the mass is seen to vary considerably, and the size of the grains of tinstone also varies. The size of the grains most abundant is generally under a quarter of an inch in diameter. Masses are, however, found from one-half to an inch in diameter, constituting in such masses more than half the weight. The proportion of albite is also variable, and the mixture presents somewhat different aspects when broken from different places, but generally the fracture shows a very brilliant uneven surface of alternate patches of the white spar, mica crystals, and black grains of tinstone. The mica has a splendent silvery luster.

This albitic greisen differs from the typical greisen of Europe in having albite with the mica instead of quartz, though the general appearance and mineralization with the tin ore are the same. The greisen of France is described by M. Manhès, and later by M. Mallard in the *Annales des Mines*, sixieme serie, X., 325, as formed of irregular fragments of mica and of quartz, appearing in the mass like a pudding-stone. It occurs at the tin mines of Vaulry, France, and is regarded as the same in origin as the veins. The tin ore of the latter locality occurs both in thin veins traversing granite in a schistose region, and also disseminated in the greisen. Von Cotta describes the greisen of Zinnwald as a granular mixture of quartz and white lithia mica without feldspar.

Percentage of tin in the greisen.—The amount of tinstone in the greisen has not yet been ascertained in the large way by working in a mill. Assays of small lots give, of course, varying quantities, depending upon the selection of the fragments. Selected hand samples of the greisen will yield from 6 to 10 per cent. of concentrate. An average, as nearly as possible taken from the outcrops in 1883, yielded about 3 per cent. of black tin, equivalent to 60 pounds in a ton of greisen. This is a high average for tin ore in the large way. The average yield in the mill will depend upon the extent to which the lower grades of ore are rejected. It is probable that it will be found profitable to mill everything that contains tin ore, even if some of it does not carry more than 10 pounds to the ton, for when mined it can be cheaply milled, and it would cost less than to sort it. Besides, there is much greisen rock which, without showing any grains of tinstone to the eye, contains enough to pay for crushing and concentrating. The quantity of tinstone developed by crushing and washing some of the masses which do not show tinstone is surprising. At the Altenberg tin stockwerk, in Germany, the rock mass contains tin ore throughout, though this is so finely disseminated as to be almost imperceptible; but it yields from 6 to 10 pounds of tin to the ton and has been extensively worked. The general average of the ores raised from the mines of Cornwall appears to be less than 3 per cent., being under 60 pounds of black tin to the short ton of ore.

There have been several shipments to New York of sample lots of tin ore from the Etta mine, consisting chiefly of the greisen ore. There have been crushed and concentrated, in a large way, by Mr. Riotte, at the New York Metallurgical Works, and from the concentrate or black tin so obtained some hundreds of pounds of block tin were smelted out in 1884. According to the certificates of the results of tests at these works one sack containing 100 pounds of greisen rock from the west tunnel in June, 1884, crushed, sampled, and assayed, showed that the average was 4.6 per cent. of black tin, equivalent to 2.95 of pure tin. This 100 pounds of ore worked on a vanner produced 4.55 pounds of concentrates, which, after roasting and rewashing, were found to contain 70.5 per cent. of tin. A sample lot of 5 tons of greisen taken from the dumps in July, 1884, by Professor Bailey, and forwarded to the New York Metallurgical Works, has yielded in 1-ton lots about 4.6 per cent. of black tin by concentration. One lot of 340 pounds weight of the massive "kidney" ore from the Etta yielded Mr. Riotte 44.1 per cent. of tin. When crushed and washed, 210 pounds of clean black tin, assaying 71 per cent., were obtained.(*a*)

Active mining operations for the production of ore have not yet commenced upon the Etta mine, but it is the intention of the company to erect extensive crushing and concentrating works, and to commence working the mine on a large scale in the course of the year 1885. The first production of tin commercially in the United States was from Dakota ore. In June, 1885, several hundred pounds of block tin reduced from the ores brought from the Black Hills by the Harney Peak Tin Mining Company were purchased by the Crooke Brothers of New York City, and manufactured into foil of a superior quality.

Bob Ingersoll claim.—At the Bob Ingersoll claim a greisen rock of a coarser grain than that at the Etta is found, but it does not carry tin ore so persistently. The cassiterite at this locality is chiefly disseminated in irregular bunches in albite, the masses of ore weighing from an ounce to two or three ounces. It is not closely associated with any other mineral or gangue, but many minerals are found in the same dike, especially columbite or tantalite in a large mass weighing not less than a ton. Spodumene has not been seen. Tourmaline is, however, very abundant, and is common in the midst of the masses of muscovite mica.

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a Condensed from the reports and certificates of working of the ores of the Harney Peak Tin Mining, Milling, and Manufacturing Company.

Beautiful lepidolite occurs also, and some of the ores of uranium in small quantity. There is also an interesting arsenical pyrites containing tin.

Western slope of Harney range.—Tin ore has been discovered also on the western side of the Harney range, particularly on Spring creek near Hill City, in lodes of regular form traversing the mica-slates and micaceous sandstones. These lodes may be grouped in two well-defined classes: (1) Quartz lodes carrying the cassiterite in crystalline masses and bunches; (2) granitic lodes or dikes having approximately the composition of granite, but carrying cassiterite in disseminated grains or crystals, generally smaller than the masses found in the quartz and darker in color. The cassiterite in the quartz lodes is generally reddish brown in color and very brittle, while the cassiterite in the granitic dikes is nearly black.

A great number of claims have been located in the Hill City district, and several are now being actively prospected and developed by the Harney Peak Tin Mining Company, preparatory to the erection of a suitable mill for concentrating the ores. The locations which have already been partly opened, and from which ore in commercial quantity has been taken, are the Mohawk, Gertie, Cassiterite, Never-sweat, Cow Boy, and the George H. Coates. Ore on these claims was visible at the surface, and has been followed down as far as the excavations have extended. It is known to occur also at other claims, as the Empire and the Harney. At the George H. Coates lode the ore is disseminated in a granitic gangue about 6 feet wide, in close association with a beautiful well-crystallized white mica. The cassiterite is crystallized in double pyramids with re-entering angles.

In these Hill City veins ore of a very high percentage can be selected by hand, and it all concentrates with great ease, as there are no heavy impurities in the veins to contend with. No combinations of tin with sulphur or arsenic have been found in the district, and wolfram has not yet been seen in association with the ore. The general course of the veins and dikes is from northwest to southeast. The granitic dikes are more regular and lode-like than on the eastern side of the range, and the crystallization is not so coarse. There is a notable absence ot columbite and tantalite. Spodumene has been fonnd in the veins of the Telegraph group. The tin ore appears in all these dikes to have been contemporaneous in origin with the minerals forming the substance of the dikes, for it forms a constituent part without any signs of alteration, penetrating the mass of quartz, feldspar, and mica as an integral portion. There is also a notable absence of titanic acid in the form of sphene, so common in the soda granites of the Sierra Nevada and the Wahsatch mountains.

Tin discoveries at Dogtown.—Discoveries of tin-bearing veins have been made by R. E. Thompson and others at a place called Dogtown, about 3 miles below Hill City, and several locations have been made.

Samples from these veins show a granitic or greisen-like gangue with disseminated grains of tinstone. The principal claims are the Carnbrea, Snowshoe, and Wild Dutchman. The Carnbrea is described as 20 inches wide, with regular walls, and opened to a depth of 17 feet. The Snowshoe is 24 inches wide, also with distinct walls, and traceable for 1,800 feet. It is opened to a depth of 10 feet. The ore from the Wild Dutchman is quartz showing included lumps of cassiterite and a sprinkling of iron pyrites.

Tin ore has also been found on Warren's gulch, 6 miles southwest of Custer City, thus extending the area of the tin-bearing region far to the south of Hill City. This discovery was made by Mr. D. P. Moore, and several locations had been made in the month of May, 1885. Other discoveries have since been reported.

Area of the tin region.—As the area of the tin region of the Black Hills is being constantly extended, it is premature to attempt to define it. It should be observed, however, that tin is not found in *all* the granite rock of the region. Much undue excitement has been caused, and many exaggerated reports have been circulated respecting the occurrence of tin in the granite of Harney peak, and hundreds of locations have been made where no tin has yet been found. Some of the prospectors at first mistook the common black tourmaline of the region for tin, and made wild and unfounded estimates of the inexhaustible supplies of ore to be mined from the flanks of the granite mountains around them. There has not probably ever been in this country a better illustration of the value of a knowledge of mineralogy to the prospector.

Stream tin in Dakota.—Stream tin, or alluvial tin ore, derived from the disintegration of the veins and rocks, occurs here in all important tin regions, and it promises to play an important part in the future development of the region. It is found, as might be expected, in the watercourses which head at and near the Etta claim, on Tin mountain, and in other places, thus giving good evidence of the existence of other veins and sources than those on Tin mountain. On Battle creek, between the Etta location and Harney City, in sluicing for gold, a large quantity of heavy black mineral in grains from the size of peas to that of pigeon eggs and larger is met with. This heavy black ore has always been a hindrance to the placer miners on that stream, and has been thrown away as useless. It is found to consist largely of tin ore of good quality; some of it shows small adherent scales of mica, indicative of its derivation from greisen, and some of it is tantalite or columbite and iron ore. It is not easy to reach the bed rock along this creek, owing to the abundant supply of water and the deficient drainage, without a bed-rock flume, which has been proposed by the gold miners for the gold alone. It is now probable that both the stream tin and the gold will be mined together, and to much greater advantage than if worked alone. Prospecting for stream tin along the valley of this creek is still in progress.

The ore has been found also on Iron creek, and later on Spring creek, about Hill City, where the breaking down of numerous veins has supplied the soil and the ravines with tinstone, as well as gold, for both are collected together in sluicing. Stream tin has been taken from Sand creek, near the Wyoming line.

WYOMING.

Tin at Nigger hill.—Tinstone has also been discovered in commercial quantities in the northwestern portion of the Black Hills, near or just beyond the line between Dakota and Wyoming, and about 40 miles from Deadwood. It is the extreme northern prolongation of the Harney Peak tin region. It first came to notice by finding that the heavy black pebbles and sand which clogged the sluices of the gold miners were tinstone of good quality. The discovery of the tin ore at the Etta claim directed attention to this, and in the year 1884, 5 or 6 tons of stream tin of high grade are said to have been collected along the course of Bear gulch and Sand creek near the Dakota line. Two or more shipments from this stream tin have been made to New York. From one lot of 4 sacks, weighing 420 pounds, Mr. E. M. Riotte obtained 400 pounds of clean black tin, which yielded 194 pounds of excellent metallic tin, or 46.1 per cent. Sample bars of this tin have also been made by Mr. S. F. Mollitor, of Deadwood, who has directed attention to this locality. In the summer of 1884 some tin lodes were discovered and many locations have been made. It is claimed in the public prints that one of the veins is "100 feet wide, and that it has been traced 4 miles." It appears that a tunnel has been run in for 100 feet, but the value of the ore found is not stated.

Samples of ore and of tin have been forwarded to San Francisco by Mr. Mark R. Hydliff, of Bear gulch. The principal claims enumerated are the Swansea, Ohio, Crow Dog, Grace, Commercial, Rough and Ready, Boston, Grant, Michigan, Morning Star, and Dakota. The ores appear to be granitic and contain considerable mica. The area of the tin district is believed to be about 4 by 8 miles. The veins are mostly on the divide between Bear gulch and Sand creek.

IDAHO AND MONTANA.

Extensive distribution of tin ore.—The many points at which tin ore has been found in Montana and Idaho indicate that it has a wide and general distribution in the granitic region of the Northwest, particularly in the Rocky mountains at the headwaters of the Missouri, and in the western drainage, including the streams flowing from the Bitter Root range, especially in the Snake and the Salmon and their affluents.

In the year 1866 attention was directed to the fact that stream tin had been found in beautiful brown grains on Jordan creek, Idaho, with gold in the placer deposits of that stream.(*a*)

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a "Catalogue of minerals found in California and the adjoining States and Territories," page 9, 1866.

A recent discovery of "float" masses of tin ore assaying 60 per cent. is reported from the Cœur d'Alenes, Idaho.

At the International Exhibition at Philadelphia in 1876, Dr. Hill of Glancy, Jefferson county, Montana, exhibited a bar of tin about 6 inches long, 2 inches wide, and 1 inch thick, which he reduced from stream tin mined in the creek at Glancy, not far from Helena. The ore at this place is found in the form of wood tin in small rounded light-brown colored grains about the size of peas or kernels of corn. It is accompanied by white brilliant crystals of topaz like those with the Durango tin ore. This wood tin closely resembles the Durango ore and that from Idaho.

Tin ore has also been found at French Bar, about 18 miles from Helena; at the head of Ten Mile in the "Basin," and in Basin gulch. Mr. Benjamin Franklin, of Deer Lodge, Montana, washed out some of the ore several years ago from Petersen creek, which heads in the main range of mountains and empties into the Deer Lodge at Deer Lodge City. These localities were described in 1882.(*a*)

TIN ORE IN CALIFORNIA.

In California tin ore has been found in the southern portion of the State in the Temescal range in San Bernardino county, southeast of Los Angeles. This locality is generally known as the "Temescal tin mines," and has excited considerable attention and absorbed considerable money in prospecting. It is a region of granitic rocks, and tinstone occurs in many places, but chiefly at the Cajalca, where a shaft has been sunk following an irregular vein or mass of amorphous cassiterite of a brown and black color. Some tons of this ore were taken out as early as the year 1860, and some tin was made from it and sent to New York. An examination of the mine and of the surrounding region was made by Mr. W. P. Blake in 1863, who found an extensive dissemination of tin ore in small quantity in various veinlets and small lodes, but particularly in a dike-like lode carrying arsenical pyrites and oxide of tin in fine powder, of a yellow-drab color, in the weathered outcrops. The shaft at the original discovery, on another lode, the Cajalca, was partly filled with water and was not then worked. An analysis of the ore from this lode by Dr. F. A. Genth showed the presence of:

	Per cent.
Silicic acid	9.82
Tungstic acid	.22
Oxide of tin	76.15
Oxide of copper	.27
Oxides of iron and manganese, lime, and alumina	13.54
	100.00

According to Capt. W. Williams, who opened the mine, there was a course of ore showing in the adit level between the two shafts for about

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a "Occurrence of Wood Tin in California, Idaho, and Montana," by W. P. Blake, *Mining and Scientific Press*, August 5, 1882.

50 feet in length and about 4 feet in thickness on the hanging wall of the lode, worth, he estimated, not less than $300 per fathom, while the whole breadth of the lode would pay to stamp. The drift, about 100 feet under the adit level, is not driven far enough to be under the bunch of ore described. Captain Williams also states that the lower drift is driven south toward and under the Cajalca hill for a distance of 300 feet, following the lode, which will average 3 feet in thickness and contains good ore in bunches. There are several small lodes or veins between the Cajalca and Temescal creek.

This region, though affording tin oxide in many places over a considerable area, has not realized the hopeful expectations of those who have made efforts to work it. The great cost of labor during and since the gold excitements of the Pacific coast, and the unsettled, uncertain condition of the title to the lands and minerals of the locality, have been two of the great obstacles to success. A decision in favor of the San Jacinto Tin Company was rendered in the United States circuit court in April, 1885.

It is stated that tin ore has recently been found farther south, near San Diego. The coarse crystalline granites of the mountain range east of that place are not unfavorable to the occurrence of tin.

In northern California a single specimen of stream tin has been reported from the alluvions of the Middle fork of the Feather river, about 3 miles above Big Bar, in Plumas county. It resembles the Montana, Idaho, and Mexican ore, and it may have been accidentally dropped there. Still another find of tin ore is reported by the *Amador Ledger*, in December, 1884, as follows: "Col. W. T. Robinson and William N. Waterman, while prospecting for gold in the neighborhood of Big Bar, on the Mokelumne river, discovered a vein of tin some 5 feet in thickness on the Amador side of the river. The ore is very similar to that found in Durango, Mexico. The find is thought to be of great importance." Such a report requires confirmation as to the nature of the ore as well as the extent. Garnet is often mistaken for tin ore.

FOREIGN SOURCES OF TIN.

Great Britain.—Tin mining in Cornwall is of extreme antiquity. Some of the most important veins have been traced over an extent of 2 miles, and they vary in thickness from a small fraction of an inch to several feet, the average width being from 2 to 4 feet, but they are subject to continued narrowing and expansions. (*a*) W. J. Henwood gives the average width of the tin veins of Cornwall as 4.7 feet. The occurrence of stream tin with gold has been noted at the stream works in the county of Wicklow, Ireland. (*b*)

The greater portion of the statistics of tin mining and smelting and of the exports of tin and of tin plate from Great Britain which are herein

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a Ure's Dictionary, article "Tin."

b *American Journal of Science*, second series, Vol. XI., page 232, 1851.

given, are drawn from the official publication upon Mines and Minerals of the United Kingdom, taken from the reports of the inspectors of mines to Her Majesty's secretary of state for the year 1883. This excellent report contains full details respecting the production of tin ore and tin in England, and also some valuable data respecting the supply of tin from the chief centers of production in other parts of the world. The production of tin ore in the United Kingdom in the year 1881 amounted to 12,898 long tons 300 pounds, valued at £697,444 5*s.* 3*d.* yielding 1,615 long tons of metallic tin, worth £839,680. This was produced in Cornwall and Devonshire, from a total of 95 mines or workings on veins, in streams, rivers, and foreshores. The production of tin ore in Great Britain in 1882 was 14,045 long tons, valued at £805,847. The ore contained 9,158 long tons of metallic tin, valued, when extracted, at £977,158. In 1883 the production amounted to 14,469 long tons, valued at £735,189, and the metal contained in the ores amounted, when extracted, to 9,307 long tons, valued at £903,476. The tin ore from mines was obtained from over 100 mines or mining properties, of which a list is given in the official report showing a yield from 1 ton or less up to 1,875 tons for Dolcoath, the largest producer. The division of the production between the mines, open works, and old mine heaps and refuse of dressing floors is shown in the succeeding table:

Production of tin ore in Great Britain in 1883.

Mines and other works.	Dressed tin ore ("black tin").			Amount of metallic tin in the ore.			Value of the tin ore at the mines or works.
	Tons.	*cwts.*	*qrs.*	*Tons.*	*cwts.*	*qrs.*	
Cornwall:							
1. Tin ore from mines	12, 756	1	0	8, 419	0	0	£665, 805
2. Tin ore from open works	203	0	0	134	0	0	10, 758
3. Tin ore from foreshores, old mine heaps, and the refuse of dressing floors	1, 439	18	1	709	8	0	54, 929
Total Cornwall	14, 398	19	1	9, 262	8	0	731, 492
Devonshire, tin ore from mines	69	19	3	44	16	0	3, 697
Total, United Kingdom	14, 468	19	0	9, 307	4	0	735, 189

In 1883 there were eight tin smelting establishments in the United Kingdom, owned and located as shown in the following list:

Bolitho, Thomas & Sons, Chyandour, Penzance.
Calenick Tin Smelting Company, Calenick, Truro.
Charlestown Tin Smelting Company, Charlestown, Saint Austell.
Danbuz & Co., Carredras, Truro.
Michell, R. R. & Co., Trereife, Penzance.
Penpall Tin Company, Truro.
Redruth Tin Smelting Company, Redruth.
Williams, Harvey & Co., Trethellan, Truro, and Mellanear, Hayle.

The yield of tin ("white tin") from the black tin as dressed and smelted in Cornwall, in 1877, was about 70 per cent. This, of course, depends upon the extent to which the impurities are removed by the washing or dressing process. In the "Mining Records" of 1853 Mr. Robert Hunt gave the average produce as about 65 per cent. In the "Mineral Statistics of Great Britain" the metallic contents of imported black tin ore are taken at 64 and 65 per cent., and even as high as 70 per cent. The following shows the average for the years named:

Years.	Per cent.
1860	64
1865	64
1870	67
1875	68¾

France.—Tin ore is found in the granitic rocks and ancient schists of the plateau of central France, especially in Brittany and Limousin and the kaolin localities of the Colettes, near Lalizolle. None of these localities, however, are of commercial importance. Numerous attempts have been made to work them, but the percentage of the tinstone is small, and the production has never been large.

The tin region of Brittany in its position and geological formation resembles Cornwall. The rocks are clay slates, mica-slates, and granite. The department of Morbihan has a great number of stanniferous veins, notably at Villeder, where there are extensive ancient excavations upon the veins, of which no record exists, but they are believed to be of the stone and bronze period, anterior to historic times. The tin-bearing lodes are composed chiefly of quartz, and vary greatly in their thickness. They traverse schistose rocks, and crop out a short distance from the borders of a great central mass of granite, which, in the vicinity of the veins, has both white and black mica in its composition. The following-named minerals are found associated with the tin ore: Muscovite, beryl, phenacite, topaz, tourmaline, apatite, molybdenite, mispickel, pyrite, black blende, chalcopyrite, galena, and several secondary minerals, such as hydrous oxide of iron and arseniates of iron, due to the alteration of mispickel. The quartz under the microscope is seen to contain an extraordinary number of liquid inclusions, apparently of water and liquid carbonic acid.(*a*)

There are also tin-bearing veins at Vaulry, true quartz veins, the thickness of which does not exceed 3 to 5 centimeters (1 to 2 inches), but they are numerous, and they traverse a granite so as to form a regular stockwork mass. The associated minerals are: Wolfram, mispickel, oxide of copper and native copper, molybdenite, and phosphate

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a Lodin: "Gites Stannifères de la Villeder;" *Bulletin de la Société Geologique de France*, 3_e Serie, t. XII., 1884, No. 8, page 656.

of uranium, near a small vein of fluorspar. Phosphate of lime and sulphate of baryta occur sparingly.(a)

The same author describes the occurrence of cassiterite in the pegmatites of Chanteloube in the quarries which have been worked for feldspar, to be used at the porcelain works. It is there associated with beryls, garnets, wolfram, columbite, apatite, uranite, triphylite, heterosite, etc.

According to the official returns of the British Board of Trade the imports of tin ore and tin into the United Kingdom from France in the year 1883 were 517 long tons of tin ore, valued at £24,184, and 24 hundredweights of tin, worth £95.

Austria.—The production of tin ore in 1882 was from two mines, and amounted to 1,051 tons. At the beginning of the seventeenth century the production of tin at Schlackenwald was about 170 tons, and at Schönfeld 80 tons annually. The mines of these districts are not now worked.

Germany.—The tin deposits of Altenberg were discovered in 1458, and formerly produced 250 to 300 tons of metallic tin annually, which, about the middle of the sixteenth century, had decreased to only 100 tons. The *zwitter*, or tin-stuff, is said to yield from 0.3 to 0.5 per cent. of tin ore. The production in 1880 of tin ore from the Altenberg mines was valued at £9,105, and from a mine at Zinnwald at £53.

Italy.—An ancient mine which had apparently been worked for tin ore was discovered in the year 1875 about 35 miles southeast of Leghorn, near Campiglia. Cassiterite occurs in irregular pockets and fissures in a limestone of the Lower Lias. This mine was probably worked by the Etruscans and ancient Romans. In 1877 the mine yielded 21 tons of tin ore. Another mine, east of Monte Fumacchio, produced in the same year several tons of inferior tin ore. In 1878 these mines produced 31 tons of tin ore, worth £384; in 1879, 2 tons, worth £16, and in 1880, 16 tons, worth £128.

Spain.—Tin ore occurs in veins and in placers in the provinces of Orense and Pontevedra. The veins traverse mica-schists and hornblendic rocks, and seldom exceed 7 inches in width. The veinstone is quartz, with some mica. Tin ore occurs also in the provinces of Salamanca and Almeria. In Cartagena tin ore is found in lenticular deposits in Permian slate. In 1880 only one mine was productive, and, according to Phillips, yielded about 12 cwts. of black tin. According to the official returns of the British Board of Trade 200 tons of tin ore, valued at £1,000, were imported from Spain in 1883. It is probable that the Phœnicians obtained some tin from Spain.

Portugal.—A small quantity of tin ore is obtained annually from Portugal, estimated at about $2,000 in value. It is found in small veins in granite and in the older slates, and as stream tin. In 1883 it is re-

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(a) Mallard: "Sur les Gisements Stannifères du Limousin et de la Marche;" *Annales des Mines* [6_e], Vol. X., page 325.

ported that fifteen tin mines were in operation. Some of these were probably placer deposits.

Russia.—The production of tin in Russia is not large. According to the following exhibit, drawn from official sources, the annual average for five years ending in 1873 did not exceed 10.2 short tons. This was from one mine and two furnaces in the government of Viborg, in Finland. The production in 1879 was only 2 tons. The export to the United Kingdom in 1883 amounted to 7 tons of tin ore, value at £173.

Production of tin in Russia.

Years.	Tin ore.	Tin produced.
	Poods.	*Poods.*
1869	213,000	1,020
1870	66,292	1,030
1871	22,909	475
1872	21,445	263
1873	5,936	130
1874	4,596	....
1875	231	....

Sweden.—This country is reported to produce not over 200 tons of tin ore per annum. The exports of tin from the United Kingdom to Sweden in 1883 amounted to 158 tons of British production, valued at £15,308, and 9 tons of foreign production, valued at £877.

New South Wales.—In New South Wales there has been a large and constantly increasing production of stream tin ore since the discovery in the year 1872. A recent geological report by Mr. T. W. E. David (*a*) gives an interesting description of the tin-bearing region. The tin placers, like the gold placers of California, are of different periods and at different elevations. There has been enormous erosion and wearing away of the surface of the older sedimentary rocks and the granites in which the tin-bearing lodes occur. The disintegration and wearing down of these lodes has supplied the tinstone to the deposits of gravel, which are now found not only in the beds of existing streams but at various levels in the hills where rivers formerly ran. Some of these higher channels have been filled with lava precisely as old river channels in California have been filled, and in each case the lava has kept the gravel of the old channel from further erosion and wearing away. It results that in New South Wales there are tin-bearing drifts of different periods, the Tertiary deposits, generally covered with basalt, being the oldest; and the existing river and creek beds containing the latest deposits, formed in many instances by the cutting away of the older and higher channels. There is such an extensive distribution of tin-bearing gravels at these different levels that it seems probable that there is little danger of the exhaustion of the field for many years to

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a Report of the under secretary for mines, New South Wales, for 1883.

come. The shallow and most accessible deposits are, however, being exhausted rapidly, and recourse must be had to the higher deposits, which will be reached by tunneling through the rim rock and drifting out the layer of tinstone on the bed rock. One of the deep channels has already been worked and the drier parts have been mostly worked out. It is said that one company took out 2,000 tons of ore from 5 acres. The exports of tin ore and tin from New South Wales (the produce of the colony) up to the year 1884 are shown in the following table:

Exports of tin and tin ore from New South Wales.

Years.	Ingots.	Ore.	Years.	Ingots.	Ore.
	Long tons.	*Long tons.*		*Long tons.*	*Long tons.*
1872	47	849	1878	6, 085	1, 125
1873	911	3, 660	1879	5, 107	814
1874	4, 101	2, 118	1880	5, 476	682
1875	6, 058	2, 022	1881	7, 591	609
1876	5, 449	1, 509	1882	8, 059	611
1877	7, 230	824	1883	8, 680	445

According to Professor Liversidge, the tin-bearing area in New South Wales is estimated at 8,500 square miles. The production up to the year 1884 was: Ingot tin, 64,794 long tons 6½ cwts.; ore and regulus, 15,268 tons 11 cwts.; the whole valued at £5,997,590. A portion of the ore smelted in New South Wales is obtained from Queensland. The ore occurs in veins and as stream tin; the veins traverse granite, and are considered to be like those of Cornwall. The ore is found also in veins of greisen, and in granulite or eurite. Sometimes the ore is found disseminated in large and well-formed quartz crystals.

Victoria.—Stream tin is found in Beechworth district, in the tributaries of the Lerderderg in the tributaries of the river Yarra; in the basin of the Thompson river, and in the feeders of the Latrobe river. In 1880 the alluvial tin ore mined amounted to 103 tons 10 cwts. In 1882, 1,077 tons of tin ore were produced; and in 1883, 94 tons 4 cwts., of which about 35 tons 14 cwts. when smelted yielded from 30 to 72 per cent. of tin. Fifteen tons 19 cwts. of tin ore were exported in 1884. The quantity of metallic tin exported in 1883 was 57 tons 14 cwts.

Queensland.—The main tin-bearing region of Queensland, according to T. F. Gregory, has an area of about 550 square miles, of which only about 225 square miles have been found sufficiently rich in tin to pay for working. The whole of this stanniferous area is an elevated granitic table land. The ore is found in veins and in the soil on the back of the veins and near them. A second tin-bearing region is known as the Great Western tin field. The number of mines in operation in the year 1881, including the washings, was 174. The annual production up to 1883 is shown in the following table, from Phillips's "Ore Deposits." The sudden increase of quantity in 1881 was due to the discovery of the Great Western field.

Amount and value of tin ore produced in Queensland from 1872 to 1882 inclusive.

Years.	Quantity.	Value.
	Long tons.	
1872	1,383	£96,840
1873	3,790	208,993
1874	3,193	160,592
1875	2,470	103,740
1876	2,325	102,030
1877	2,519	94,462
1878	1,178	35,340
1879	3,142	106,010
1880	1,553	47,300
1881	106,448	2,168,790
1882	27,312	560,590
Total	155,313	3,684,687

In regard to the production of the colony for the year 1883, a communication to the London *Mining Journal* from Herberton, North Queensland, November, 1884, states that the quantity exported from Herberton district alone amounted to 2,821 tons 12 cwts., valued at £151,903, and there being then no smelting works for tin in Queensland the whole product was shipped to Sydney, New South Wales, and was included in that colony's exports, and received in England as the product of New South Wales, while Queensland for the same period was officially credited with only 22 tons of tin ore. Herberton is now the largest tin-producing district in Queensland.

Tasmania.—Tin ore was discovered in Tasmania in 1872, in the northwestern part of the island at Mount Bischoff, 54 miles from the port where the ore is now shipped. The ore occurs in porphyry in strings and lodes irregularly. Up to 1875 only one well-defined lode had been laid bare. The deposits in the surface earth are frequently extremely rich, while other places near by are poor in tin ore. On one section 240 tons of tin ore were taken from an area of wash dirt only 60 feet square. Tin ore is also found at Mount Ramsey, 10 miles from Mount Bischoff. This mountain is composed chiefly of a coarse-grained granite, containing tourmaline. The ore is also found at Wombat Hill and at Mount Housetop. On the east coast stream tin is found near the source of a small river known as the Golden Fleece. The tin-bearing formations have been traced for a great distance to the northwest.

In 1876 the value of tin ore and ingots exported from Tasmania was £100,000; in 1877 it was £296,941; in 1878, £316,311; in 1880, £341,736, and in 1881, £375,775. In 1883, according to the official customs returns, the exports to the United Kingdom amounted to 2,288 cwts. of tin, valued at £10,770.

Straits Settlements.—These comprise Singapore, Penang, Province Wellesley, and Malacca. The tin ore of Malacca occurs in quartz veins traversing granite. The tinstone of Perak is light colored and is often translucent. It is obtained from alluvial deposits, not from the lodes, The exportation of tin for five years, ending with 1880, is shown in the following table:

Years.	Laront.	Lower Perak.	Total.
	Long tons.	*Long tons.*	*Long tons.*
1876	1,783	271	2,054
1877	2,511	547	3,058
1878	2,895	739	3,634
1879	3,478	848	4,326
1880	4,406	1,038	5,444

The aggregate value of this production is stated at £450,000. The exports in 1882 amounted to 7,000 long tons, and about 40,000 Chinamen were employed. The tin is sent to Penang, which receives also the tin produced in Siam. (*a*)

The *Journal of the Société de Géographie Commerciale* for 1884 states that in Lower Perak and Kinta, the principal mining districts are Olon-Kinta, Chandenong, Chemor, Yanka, and Khan-Baron, which in 1880 exported 1,038 tons, while the total tin exports of Perak have risen from 3,054 to 5,444 tons in four years, their total value being estimated at £4,500,000.

The Straits shipments in 1883 to the United Kingdom amounted to 280,235 cwts., valued at £1,310,453.

Dutch East Indies.—The islands of Banca and Billiton, noted for their production of tin, are formed of granitic masses in the midst of Silurian slates and quartzites. The tin ore is obtained chiefly from placers. The production in 1882 was 8,550 tons of metallic tin, part of which was sent to China. The East Indies have long been celebrated for the quantity and fine quality of the tin exported. Banca furnished the chief supply, in addition to the product of Cornwall, until the discovery of the mines of the island of Billiton in 1851, followed, in 1873, by the development of the tin deposits of Australia. Banca tin is sent to Holland in slabs which average about 64 pounds in weight, 1,000 weighing about 32 tons. This tin is sold by the Dutch Trading Company. In 1881 the sales amounted to 135,592 slabs, at prices ranging from 53 to 64 florins per kilo. In the same year 78,000 piculs of Billiton tin were sold in Batavia at prices ranging from 60.33 to 75.43 florins per picul. The following figures give an idea of the production of the Dutch tin regions and the exportation from them:

	Long tons.
Banca sales in 1881	4,339
Billiton	4,735
Straits shipments to London	5,795
Straits shipments to the United States	5,680

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[a] Phillips: "Ore Deposits," page 444.

India.—Tin oxide occurs at Nurunga, in the Bengal presidency, in lenticular beds in gneiss seldom over a foot in width, and sometimes 60 feet in length. According to Phillips, about 8 to 9 cwts. of metallic tin was obtained from the ore about fifteen years ago. A few specimens of cassiterite have been found in Bombay.

Burmah.—Tennasserim, in British Burmah, yields tin ore occurring in a decomposed granite, in a vein about 3 feet wide. Some 1,200 pounds of the washed ore were sent to the India House.

Japan.—A small amount of tin is produced annually in Japan. (*a*) It is reported to occur in three out of the thirty-five ken. According to Mr. Godfrey, the total yield in 1874 was 16,800 pounds. At the Taniyama mine, said to be owned by the Prince of Satsuma, there are twenty-one veins averaging 1½ feet in thickness, or from a few inches to 4 feet. These veins traverse sedimentary rocks, similar to the formations at Yamagano, composed of soft tufas, shales, and sandstones, with occasional beds of hard blue quartzite. The surface is covered with recent pumice. The ore is cassiterite in small microscopic crystals, and the rock is said to contain from 12 to 13 per cent. of black tin. It is crushed and ground between millstones and concentrated on the "ita" (panning out) to about 50 per cent. One ton of concentrates requires eighty days' work. The yield is stated at about 2,500 pounds per month or about 13 tons annually, though according to Phillips the product is about 8 tons annually. It was 7 tons in the year 1875. Japan imports considerable quantities of tin, used in the manufacture of bronzes.

China and central Asia.—We know very little of the production of tin in the interior of China and in central Asia. It is well known, however, that there is an important tin-bearing district up the Yellow river in a granitic region. The principal localities are those of Laos and Yan, described or noticed in a report to the French Government by Fuchs and Saladin, and translated by Charles Smith, Institute of Civil Engineers, London. See also *Annales des Mines*, 1882, ii., 185–298. At Yan it is said that tin and salt are bartered evenly, weight for weight. In consequence of the "Black Flags," the quantity of tin annually brought to Hà-Noi was only 1,000 tons, instead of from 3,000 to 4,000 tons, as before the year 1874.

Mexico.—The principal locality of tin ore in Mexico of which we have any knowledge is in the State of Durango, in a somewhat inaccessible region where transportation is costly. The ore brought from there is a superior quality of wood tin in granules and masses from the size of peas and beans to nodules as large as eggs. It is washed tin ore from the beds of ravines, and appears to have originated in a trachytic dike from which it has been disintegrated. The quantity appears to be considerable. It is associated with topaz in clear white crystals. Several attempts have been made to utilize the tin ore of this locality, but

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[a] "Transactions American Institute of Mining Engineers," Vol. V., page 297.

hitherto without success, for various reasons. A bar of tin weighing several pounds was made from this ore by Mr. Joseph Wharton, of Philadelphia, several years ago, and in September, 1883, a ton of metal from this region was reported as arriving in the United States. It is also stated that the placer ores yield a high percentage of tin, and that capital from Saint Louis is interested in the development of the region, which is near to the famous iron mountain of Durango.

The *Tribuna*, of Durango, reports that about 90 miles northwest of that city and 125 from the station of Villa Lerdo, on the Mexican Central railroad, is the small town of Coneto, with about 1,000 inhabitants, and situated in the center of the tin region of Mexico. It bears traces of having been much larger in size and a very prosperous mining town. It lies in a gulch at the foot of a chain of mountains, called San Francisco, and its population derived and still derives its living chiefly from mining and smelting tin ores, found in the above mountains. The San Francisco chain is one of the lateral branches of the main chain of the Rocky mountains, and is about 100 miles in length and 40 to 60 miles in width. Throughout its length and width it is a series of abrupt peaks, rocky cañons, and some occasional grassy slopes and long but narrow valleys. The whole of it is heavily wooded with oak and pine, but is almost waterless, although during the rainy season many unfordable mountain torrents are met with there, and the grounds offer at many points facilities for damming, where a short dam, if built, would entrap an extensive reservoir or a series of reservoirs of water. Toward the southwestern end of this ridge is the central point of the Mexican tin region. Its extent is about 150 miles in length and about the same in width. The tin ore found there is principally brown and black cassiterite of extreme purity, and this is found either in veins which fissure in all directions these peaks and their slopes, or in placers, in gulches, and valleys at the foot of the peaks and slopes. At the foot of all ridges and slopes where a vein exists a placer of tin is invariably found. Sulphuret of tin has also been found, but, so far, only in one point of these mountains, while arseniate of tin and also very finely divided red oxide of tin, are met with in many of the numerous veins already tapped. The massive cassiterite is usually found in the veins in continuous streaks of various width, the ore being, of course, easily separated from gangue and containing from 70 to 89 per cent. of metallic tin. The veins are very numerous, and although many of them are cut into, and some have been worked quite extensively, it is a certainty that only a small percentage of them are known at present and a great many more could be found by judicious prospecting.

A discovery of a vein rich in tin ore is announced in Lower California about 60 miles east of Real del Castillo, in the Cocopa mountains. It is in a region occupied by Indians, and has not been worked. Samples sent to San Francisco and San Diego gave good results in tin. The pay streak is from 2 to 4 feet wide. (*a*) It is thought to be in a formation corresponding to that in which the Temescal tin veins are found.

South America.—Small quantities of tin ore and tin are annually produced and exported from several of the South American states. In 1883 the imports into the United Kingdom from South America were:

Imports of tin ore and tin into Great Britain from South America in 1883.

From—	Tin ore.		Tin.	
	Quantity.	Value.	Quantity.	Value.
	Long tons.		*Cwts.*	
Peru	131	£7, 098	648	£2, 878
Chili	37	2, 037	618	2, 815
Argentine Republic	....	....	2, 630	11, 127

The exports of tin for the same year from the United Kingdom to these and other South American states were:

Exports of tin from Great Britain to South America in 1883.

To—	Quantity.	Value.
	Long tons.	
Peru	5	£509
Chili	14	1, 453
Brazil	81	8, 138
Uruguay	35	3, 562
Argentine Republic	33	3, 343

PHYSICAL PROPERTIES OF TIN.

Tin is a silvery-white metal with a yellow tint. It crystallizes in modification of the square prism. Its hardness is greater than the hardness of lead, and it is softer than zinc. It is not very ductile, but is very malleable. It may be beaten into leaves or foil only a thousandth part of an inch in thickness. The specific gravity ranges from 7.28 to 9.60, according to the purity. It melts at 442° F., and at a temperature much above its melting point it volatilizes. Bars of tin when rubbed emit a metallic odor.

Cry of tin.—The "cry of tin" is the peculiar crackling sound produced when a rod of tin is bent back and forth. It can be distinctly heard when the rod is bent near the ear, and those accustomed to it judge of the purity of the metal by the sound produced.

Purity of commercial tin.—The tin of commerce generally contains a very small quantity of iron and lead and traces of other metals, but rarely exceeding 1 per cent. of impurity. The tin ores of Cornwall taken from the veins yield metal which is less pure than that extracted from the ore washed out of the beds of streams. The stream tin ore is

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[a] D. K. Allen, in London *Mining Journal*, October 11, 1884.

less contaminated with sulphur and arsenic. The metal from the mine ores is commercially known as "mine tin" and that from the alluvial washings as "stream tin." The purest form of tin in commerce is called "grain tin," and the ordinary quality "block tin." The metal known as "crude tin" is contaminated with various other metals in small quantities but sufficient to render the tin hard and difficult to fuse. It is refined by liquation and by steaming, and is then called "refined tin." Impure tin is also known as "raw tin." A very small amount of some of the metals greatly impairs the quality. Copper is not as hurtful as iron or arsenic, bismuth, or antimony. One-half of 1 per cent. of these metals makes the tin harder and less ductile. One per cent. of iron makes it friable and dark in color. The purest tins are from Malacca, Banca, and Billiton. Banca tin, known in England as "old tin," commands the highest price. Other India tins are known as "new tin." Banca tin is sold in blocks of 40 and 120 pounds. Malacca tin is pyramidal in form and the masses weigh from one-half to 1 pound. English grain tin is sold in blocks 2 feet long, 1 foot broad, and 8 inches thick. Inferior grades of English tin are sold in bars under the name of "Japanese tin." "Ball tin" is formed by pouring the metal upon a polished plate of copper and then rolling it into balls, which are beaten with hammers and are then stamped.[a]

The United States commission for testing metals had analyses made of two of the finest tins obtainable, with the following results:

Analyses of ingot tin.

	Banca.	Queensland.
	Per cent.	*Per cent.*
Metallic iron	0.035	0.035
Arsenic		Trace.
Lead		0.165
Manganese		0.006
Tin	99.978	99.794
Insoluble in aqua regia	Trace.	
	100.013	100.000

Powdered tin is, as the name implies, the metal in a highly divided state, produced by shaking it when poured in a wooden box rubbed with chalk on the inside. It is used in the arts to overlay metals or other substances with a thin layer of tin. It is first painted on in a solution of glue or sizing and when dry is burnished and varnished. It gives a brilliant and durable surface of tin.

Permanence of polished surface of tin.—Burnished tin and tin plates retain their brilliancy for a long time if kept from contact with damp and salt air. Roofs and domes of buildings in the interior of the country far from the sea, covered with tin plate, retain the silvery bright-

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[a] These observations upon the purity of commercial brands of tin are condensed from the treatise of Crookes and Rohrig.

ness of the metal for years, and do not require painting. Brande cites the fact that burnished tin on one of the pages of a missal of the ninth century, in Alfred's time, still retained its brilliant white luster, although a thousand years had passed since it was laid upon the vellum.

Tin foil.—The great malleability of tin has already been mentioned. It is not only beaten, but is rolled into foils of various degrees of thinness. The value of the metal as compared with lead has led to the invention by Mr. J. J. Crooke of coating the surface of lead sheets with a layer of tin and rolling the two metals out together. The desired weight and strength of the foils are thus secured without using much tin, the greater thickness and weight consisting of the lead upon which the pure tin is spread. Most of the beautiful foils now manufactured for wrapping tobacco and cigars, for capsules, for wine bottles and for jars, are now made in the way described. Great care should be exercised to prevent the contamination of food by the decomposition of the lead of such foils.

Argentine.—The *Engineer* says the product known in commerce as "argentine" and which is used for printing upon cloths and paper, is a tin moss or sponge obtained by precipitating tin from the chloride solution by zinc. The tin solution must be acid and diluted until it contains 15.85 gallons of water for 150 grams of the tin salt, or in that ratio. The metallic sponge must be carefully collected, washed, and dried. It is then pulverized with water in a mortar, passed through a fine hair sieve, and is mixed with starch paste for printing. The *Chronique Industrielle* says the gray powder can be economically employed for tinning all metals but lead.

Tinning copper.—Tin is largely used, not only for coating iron and mild steel sheets, but also for tinning the surface of copper. Culinary vessels of copper are usually tinned upon the inside to prevent the solution of a portion of the copper by the acids and salt of food in cooking. In France, where such vessels are much used, the tin coating is frequently renewed. Brande gives the following directions for performing the operation: The interior of the vessel is first cleaned and the surface is rubbed over with sal ammoniac; the vessel is then heated, a little pitch [or resin] is rubbed over the surface to be tinned, and tin is applied until the coating is formed. There is usually an excess of tin which is liable to melt off and get into the food when the vessels are first used.

Disintegration of tin.—It has long been known that tin in pigs and in plates is subject to a peculiar form of disaggregation, especially when exposed to extreme cold and great changes of temperature. The following item from the columns of the *Mining and Scientific Press*, copied probably from a European source, gives a succinct statement of some of the observed phenomena: "The question of the real causes of the so-called disaggregation of tin remains still an open one. Thin sheets of the metal will sometimes, if exposed to the cold for long periods, be covered with blisters, become brittle, fall to pieces and finally to powder. The crystalline texture assumed under the influence of cold has been advanced as the probable cause of this peculiarity, while Professor Rammelsberg suggested a dimorphism of tin based on investigations which revealed a decrease of specific gravity in the disaggregated tin, the common specific gravity being 7.29, and that of this modified tin only 7.14. A case was reported in which good commercial tin with the usual amount of 3 per cent. of lead was, during its transport from Rotterdam to Moscow in a very cold winter, changed into the gray powder described by prior observers. Discussing this and other occurrences, it was pointed out that continuous vibrations, such as would result from variations of temperature, probably exerted considerable influence in promoting phenomena as here mentioned. The following remarkable occurrence, however, clearly shows that continuous concussions are not absolutely necessary to produce this phenomenon. In a corner of a window in Freiberg cathedral, that had been built up for a long time, a wooden box was found, which, when opened, not without some shaking, showed the fragments of a tin medal and ring, small pieces of a reddish-gray color with the surprisingly low specific gravity of 5.8. In this case, as in the others mentioned, a metal with the usual brightness, specific gravity, and other qualities of tin was re-obtained simply by heating the gray pieces to the temperature of boiling water. At present, attention is drawn to this phenomenon by an observation of Mr. W. Markownikoff, of Moscow. Some of the tin cans kept in a cold room in one of the Government buildings at Moscow showed blisters, then holes, and finally fell to powder. Once set in, the process could not be stopped by removing the cans to a warm room; the destruction ceased, however, if the attacked spots were cut out. None of the cans in use exhibited this disaggregation. Mr. Markownikoff thinks that more or less rapid cooling predisposes the tin to this decay, which is favored by low temperatures."

Similar phenomena have been observed in a lot of bar tin stored in Boston in the winter of 1882–'83. At the meeting of the American Institute of Mining Engineers in Boston, February, 1883, Prof. R. H. Richards exhibited bars of tin covered with blister-like protuberances with a coarsely crystalline structure, while the tin was changing from its malleable to a powdered condition, becoming friable, brittle, and earthy in appearance. These bars were made from a lot of tin amalgam. After the mercury was distilled off completely, as was supposed, the remaining fused tin was poured into molds, and when cold the bars appeared to be block tin of good quality. Two months later the bars gave signs of falling to pieces. They changed color and assumed the condition described. An analysis showed the composition of the metal to be as follows;

Analyses of disaggregated tin.

	Crystalline part.	Malleable part.
	Per cent.	*Per cent.*
Mercury	2.62	2.38
Tin	97.24	97.50
Total	99.86	99.88
Specific gravity	6.175	7.387

The presence of mercury thus seems to have been the cause of the changes in the metal. It is probable that other cases of the decay of tin have been similarly produced.

ALLOYS OF TIN.

Alloys of tin and copper.—Bronze metal, formed of tin and copper, is the most important alloy of which tin is a component part. The extreme antiquity of this alloy, and its general use before the age of iron for arms, ornaments, and statues by prehistoric and ancient nations, are well shown by the multitude of bronze objects gathered in the archæological museums of Europe. It is found also that the weapons of Scandinavian, Celtic, Egyptian, Greek, and Roman warfare were made of nearly the same alloys of copper and tin, contained in the same ratios as in modern gun-metal. (*a*) This ratio ranges from 8 to 10 parts of tin in 100 of alloy. Compressed ordnance bronze of the United States is formed of 10 parts of tin and 90 parts of copper. Its specific gravity is 8.669; color, grayish yellow; tenacity in pounds per square inch, 26,860, and its relative ductility, 18. These results were obtained by the United States board for testing iron, steel, and other metals. (*b*) According to Calvert and Johnson the mean composition of 83 gunheads was 88.97 of copper and 11.03 of tin. The composition of bronze for medals is generally 8 parts tin and 92 of copper. Carriage-wheel boxes are made of 16 parts tin and 84 of copper. A Chinese gong, according to Thurston, was composed of 19.57 tin and 80.43 of copper. The bells of Reichenhall, three hundred years old, were made of an alloy of 20 of tin and 80 of copper. Another bell, six hundred years old, was made of 76.20 copper and 23.80 tin. Swiss clock bells (brittle) contain 24.80 tin and 75.20 copper. Mirror metal contains 31.70 tin and 68.21 copper. White bell metal is composed of 40 tin and 60 copper.

The properties of alloys vary not only with the composition, but with the conditions of melting, pouring, annealing, and working. The order in which the constituents of mixture are melted affects the properties of the alloy. Thus 90 parts tin and 10 of copper, with the addition of 10 of antimony, combined in the order stated, give an alloy

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a Mattel: "Construction of Artillery," London, 1856, pp. 80–101.

b Prof. R. H. Thurston, chairman; *vide* report on copper-tin alloys, 1879.

which totally differs from one formed by melting the metals in the reverse order. The composition probably is not the same. It is found that with some metals very slight difference of composition makes great changes in the physical characters and properties of an alloy. Thus, according to Bischoff, the injurious effects of 1 part of tin upon 10,000,000 parts of pure zinc can be detected. One-half of 1 per cent. of lead will reduce the strength and ductility of bronze nearly one-half. The density of bronzes varies greatly with the rapidity of cooling them from a state of fusion. Riché found, contrary to the received statement, that tempering bronze increases rather than diminishes its density. The reverse is the case with steel. Plunging the metal while hot into cold water, which hardens steel, softens copper and its alloys with tin. Hammering also acts differently upon bronze and on steel. In making Oriental tam-tams and cymbals the metal is rapidly hammered while hot. Attempts to make such instruments in Europe with Chinese metal have been unsuccessful. Riché also states that bronzes containing from 2 to 4 per cent. of tin are not much harder than copper. Analyses of antique medals of bronze show that the amount of tin varies from 1 to 25 per cent. The hardness of bronze is the great objection to its use for medals when high reliefs are desired, as in the medals of the present time. Ancient medals are not in such high relief. The hardness of bronze increases rapidly with the amount of tin.

Alloys of tin and copper are known to resist oxidation better than the component metals singly. The durability of ancient bronzes exposed to the weather is well known. Nitric acid acts with less energy upon bronze than upon pure copper, but the conservative influence of the tin diminishes as its quantity in the alloy increases. An alloy of tin and lead in the ratio of 3 of lead and 1 of tin is, on the other hand, much more oxidizable than the component metals. When heated to redness it takes fire and burns.

Alloys of tin for bearings of machinery.—Alloys of tin with copper, lead, antimony, and zinc have been made in great variety for journal boxes—the bearings of machinery. Phosphorus has also been added to copper and tin alloys for journal bearings.(*a*) It is claimed that an alloy of tin, zinc, copper, and antimony heats very little by friction.(*b*) White metal alloys for machinery, with alloys fusible at specified temperature, are described in *Van Nostrand's Magazine*, 1869, page 172. For crank and connecting-rod bearings the following compositions are given: 90 tin, 8 antimony, 2 copper; for pivots, slide valves, etc., 78.5 tin, 11.5 antimony, 10 copper; for locomotives (Swiss), 80 tin, 10 antimony, 10 copper.

Properties of copper, zinc, and tin alloys.—As the result of elaborate experimental trials and studies of the properties of copper, zinc, and

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a Dick: Improvement in alloys of copper for journal bearings. U. S. patent, April 9, 1872, No. 125,549.

b Dunlevie: *Dingler's Journal*, No. 177, 1865, pp. 326, 327.

tin alloys, Professor Thurston finds that the alloys of the maximum strength are grouped about a point not far from copper 55, zinc 43, tin 2, as shown upon a triangular model in which the different degrees of strength are shown by different degrees of relief or elevation above a common base. The point of maximum strength is encircled by a line marking 65,000 pounds per square inch tenacity. This is the strongest of the bronzes, and Professor Thurston says that an alloy of this com position, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce a sound and pure metallic alloy, with such prompt cooling as shall prevent liquation, is the strongest bronze that can be made.

Naval brass.—An alloy called "naval brass" has been introduced in ships of the Royal Navy, to take the place of the Muntz metal, which was frequently found to decompose under the action of sea water. Bolts which appeared to be perfect on the surface were found to be decayed in the interior, as if permeated by sea water. According to the *Engineer*, in the latter part of the year 1879 an alloy "composed of 62 parts of copper, 37 of spelter, and 1 of tin, was proposed by Mr. Farquharson, as possessing the requisite mechanical properties. The Admiralty thereupon referred the question as to the endurance of such metal to Dr. Percy, of the Royal School of Mines, in conjunction with Mr. Farquharson. These gentlemen, after subjecting an alloy of this description to severe tests, under which the Muntz metal completely failed, reported to the Admiralty in 1879 that the new compound had stood the tests satisfactorily. Accordingly it was adopted as the service alloy, under the title of 'naval brass.' The process of manufacture is the same as for yellow or Muntz metal. To insure the best results, Australian or English B. S. copper should be used, and the proportions of metal stated above closely adhered to, due allowance being made for the loss of zinc in the process of melting. When finished cold, and left unannealed in rods and sheets of moderate thickness, the metal has a tensile strength of from 67,000 to 72,000 pounds per square inch, according to the amount of rolling it has received. Bolts of any size can be made of it, the usual practice being to take a rod the size of the bolt required, and to form the head by upsetting in a die. This is done without stress or injury to the metal, in a bolt or rivet-making machine with heads two diameters of the bolt."

Tin and iron alloy.—A very small quantity of tin is injurious to iron. Karsten found that 1 per cent. of tin added to iron made the iron extremely brittle when cold, but not when hot, for the iron could be forged but gave out white vapors which condensed on the anvil. Mr. Billings, who has made special experiments with alloys of tin and iron, finds that an almost insignificant quantity of tin, in the absence of other metals, renders iron cold short, and that it has a most hurtful effect. (*a*)

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a "Transactions American Institute of Mining Engineers," Vol. V., page 450.

Argasoid.—A new alloy, called "argasoid," is described by Mr. V. Jeuptner, of Vienna, and has been used as a substitute for silver. It's composition is tin, 4.035; lead, 3.544; copper, 55.780; nickel, 13.506; zinc, 23.198; iron, trace.

Tin and lead.—The well known alloy called pewter consists of tin and lead, and the proportions vary with different manufacturers. The pewter of beer mugs is made of 20 parts of tin and 1 of copper, with addition of lead, zinc, bismuth, or antimony, according to the recipes and fancies of the makers. Soft solder is a compound of tin, lead, and bismuth. Riché has found that the maximum of contraction of an alloy of tin and lead corresponds exactly to the alloy SnPb, and he regards this alloy as a distinct chemical compound. With tin and bismuth the maximum of contraction is found in the alloy $BiSn_5$, which alloy is silvery white and is not attacked by distilled water.

Britannia metal.—This is an alloy formed chiefly of tin and antimony, with some copper. The proportions vary, but the following is common: Take 350 pounds of the best block tin, melt it and raise it to a dull red heat; add 8 pounds of melted copper, stirring to effect a complete mixture, and 28 pounds of antimony and 8 pounds of brass, also in a melted state. A large quantity of tin is consumed annually in making this alloy.

Terne-plate alloy.—Tin is alloyed with lead for the manufacture of "terne plates," the alloy being cheaper than pure tin for coating the iron. Such plates are far inferior to tinned iron in durability, and besides are very dangerous if made up into culinary vessels, or if used for canning fruits or vegetables. At one of the meetings of the California Academy of Sciences, Dr. Henry Gibbons, sr., exhibited some sheets of pure and adulterated tin, such as are used for canning vegetables, etc. He suggested that probably cases of poisoning which had been reported, where people had eaten vegetables, fruit, etc., from tins, were due to the lead used with the tin to cheapen it. Acids developed by fermentation, acting on the lead adulteration, take up lead, arsenic, and antimony from impurities in the lead and tin alloy. Salts of lead are all more or less poisonous, and produce colic. It has, unfortunately, become too common to adulterate pure tin with lead, to cheapen its cost in making cans. Asparagus packed in cans made of such impure tin has been found to contain a little tin and considerable lead, and similar results have been obtained by the analyses of acid fruits packed in cans. The salts of lead are much more poisonous and are more soluble than tin salts, and the use of adulterated tin plates should be carefully avoided in making cans in which food is to be packed.

Tin pretended to be extracted from iron slag.—The faith and hopes of alchemy of the Middle Ages do not appear to have been entirely extinguished by modern science. At least the credulity of mankind is ever ready to seize upon short roads to wealth by the supposed possible transmutation of metals. This ignorant credulity was utilized during the past year by persons in New York who pretended to be able to extract large quantities of a white metal from blast-furnace slag, by introducing a small quantity of a powder into a crucible containing the melted slag. It is surprising that such a transparent hoax should have received so much consideration.

Oxide of tin.—"Putty powder," or "putty of tin," as known in the arts, is used chiefly to give the highest polish to glass after cutting. Considerable quantities have been imported into the United States, as shown in a subsequent table.

THE TIN-PLATE INDUSTRY.

The manufacture of tinned-iron plates appears to have originated in Bohemia several years before 1620. In that year the manufacture was commenced in Saxony, and from Saxony the industry was introduced into England in 1670, but did not become firmly established until the reign of George I., in 1720.(*a*) The process of tinning small articles of iron and copper was known long before either of these dates. Pliny says that tin-coated vessels were scarcely to be distinguished from silver.(*b*) It is not known whether the *vasa stannea* of the Latin authors were formed of cast tin or of tinned bronze.

Great Britain.—Very few tin plates were imported into England after 1740. The manufacture of tinned plates was continued and developed chiefly in Monmouthshire, and at the present time the chief centers of production in Great Britain are in South Wales, Monmouthshire, Staffordshire, and Worcestershire. Mr. Ernest Trubshaw, in a paper read before the Iron and Steel Institute of Great Britain, at London, in May, 1883, says that the tin-plate industry at the present time consumes annually nearly 500,000 tons of pig iron, probably 1,000,000 tons of coal, about 10,000 tons of tin, and large quantities of sulphuric acid, palm oil, and lead. Large quantities of sulphur, for making the sulphuric acid, are imported chiefly from Sicily, but a large supply is obtained by Messrs. Vivian & Sons from the waste gases of their copper-smelting works. Mr. Trubshaw's statistical figures, showing the extension of the trade since 1858, are as follows:

In the United Kingdom, according to the returns of Her Majesty's inspectors of factories, there were in 1883 in Carmarthenshire alone 68 mills for making tin plates, 49 of which were working, and produced for that year 1,076,354 boxes of tin plates, 155,713 boxes of terne plates, and 62,618 boxes of black plates, a total weight of 68,608 tons. The summary for the whole kingdom gives 386 mills, of which 295 were working, and produced 4,789,115 boxes of tin plates, 964,180 boxes of terne plates, 361,905 boxes of black plates; total, 6,115,200 boxes, weighing 315,997 tons. These figures show the magnitude of the tin-plate industry of Great Britain. The exports of tin plates and terne plates,

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[a] P. W. Flower: "History of Tin Plates," page 37.

[b] *Ibid.*, page 24.

as shown by the Board of Trade returns, have been as follows since 1862:

Exports of tin plates and terne plates from Great Britain.

Years.	France.	United States.	British North America.	Australia.	Other countries.	Total.
	Cwts.	*Cwts.*	*Cwts.*	*Cwts.*	*Cwts.*	*Cwts.*
1862	44, 611	590, 827	32, 306	18, 736	314, 957	1, 001, 437
1863	51, 974	669, 188	40, 708	21, 873	332, 184	1, 115, 927
1864	50, 018	535, 590	36, 091	19, 060	362, 810	1, 003, 569
1865	55, 506	845, 263	21, 921	17, 461	314, 216	1, 254, 367
1866	33, 582	1, 076, 778	47, 610	15, 397	216, 206	1, 419, 573
1867	60, 027	1, 060, 224	46, 959	26, 790	385, 692	1, 579, 692
1868	38, 343	1, 250, 909	48, 188	42, 544	388, 144	1, 768, 128
1869	37, 826	1, 472, 445	55, 781	41, 680	326, 302	1, 934, 034
1870	25, 158	1, 507, 463	59, 648	62, 728	346, 588	2, 001, 575
1871	42, 460	1, 738, 580	84, 000	102, 820	424, 240	2, 392, 100
1872	66, 840	1, 747, 200	80, 060	101, 880	365, 680	2, 361, 660
1873	78, 820	1, 710, 620	66, 860	86, 520	466, 540	2, 409, 360
1874	46, 660	1, 828, 140	70, 240	51, 880	462, 280	2, 459, 200
1875	63, 720	1, 919, 900	82, 680	63, 840	637, 120	2, 767, 260
1876	114, 660	1, 804, 640	88, 980	78, 760	560, 900	2, 647, 940
1877	104, 440	2, 131, 860	181, 200	87, 060	559, 960	3, 064, 520
1878	107, 660	2, 162, 480	108, 940	73, 940	648, 400	3, 101, 420
1879	108, 980	3, 115, 900	117, 300	48, 500	566, 300	3, 956, 980
1880	84, 380	3, 283, 340	208, 060	89, 260	691, 320	4, 354, 360
1881	111, 440	3, 594, 880	234, 940	165, 780	741, 920	4, 848, 960
1882	81, 180	4, 291, 040	173, 200	117, 420	637, 580	5, 300, 420
1883	76, 140	4, 254, 480	248, 040	104, 480	704, 200	5, 387, 340
1884	92, 600	4, 237, 200	322, 300	121, 160	1, 000, 900	5, 774, 160

Average prices of tin per ton and tin plates per box at Liverpool.

Years.	Coke tin plates.		Tin.			Years.	Coke tin plates.		Tin.		
	s.	*d.*	£	*s.*	*d.*		*s.*	*d.*	£	*s.*	*d.*
1865	21	10½	91	10	10	1875	22	11	84	11	8
1866	23	6½	80	11	8	1876	19	3¾	74	7	1
1867	22	7½	87	7	6	1877	17	6¾	69	5	5
1868	20	11½	93	9	2	1878	14	9	61	4	2
1869	21	10½	125	8	4	1879	17	3½	71	13	4
1870	21	11½	125	10	0	1880	19	1¼	86	5	5
1871	23	7	133	2	6	1881	15	4¼	92	8	4
1872	34	8	144	18	4	1882	15	11½	102	13	4
1873	31	3	132	17	6	1883	15	11½	92	17	3
1874	27	3	97	11	8	1884	14	10	81	5	0

The average price of coke tin plates in the ten years, 1875–1884, was 17*s.* 3¾*d.*, while that of charcoal tin plates during the same period was 21*s.* 10¾*d.*

United States.—A company called the United States Tin Plate Company was organized in 1874 for the purpose of manufacturing tin plate in the United States. Very little plate was made and the effort was soon abandoned. According to the *Age of Steel* (1883), there were no tin plates produced in the United States, and the same is true for 1884, although there were nine rolling mills altogether having facilities for making them, namely, the Leechburg Iron and Tin Plate Works, Leechburg, Pennsylvania; the Granite Iron Rolling Mills, Saint Louis, Missouri; the United States Iron and Tin Plate Works, McKeesport, Pennsylvania; the Apollo Iron Works, Apollo, Pennsylvania; the Bay State Iron Company, Boston, Massachusetts; Marshall Bros. & Co., Philadelphia; Alan Wood & Co., Conshohocken, Pennsylvania; the Cannonsburg Iron Works, Cannonsburg, Pennsylvania; the Wellsville Plate and Sheet Iron Company, Wellsville, Ohio. The three first named have complete tinning departments connected with the works, and the remainder have all the facilities for making tin plate or tinned iron, except the tinning bath.

Parties interested in the manufacture of tin plate have organized a Tin Plate Association, the object of which is to introduce, foster, and develop the tin plate industry in the United States.

During the year 1884 there has been an animated discussion in some of the leading industrial journals upon the feasibility of establishing a profitable tin plate industry in the United States. With foreign tin nearly as cheap in New York as in Liverpool, the possession of all the needed materials is conceded by both sides; the obstacle appears to be the greater cost of labor in the United States than in Wales and England. The amount of tin plates imported in 1870 is stated at 75,467 short tons, which had increased to over 240,000 tons in 1883. This amount of tin plate is claimed to represent in wages an amount equal to that which is necessary to produce 1,000,000 tons of steel rails. (*a*) The discovery of a tin-bearing region in the Black Hills, Dakota, from which a supply of tin of domestic production may be obtained, gives additional interest and importance to this discussion.

There are no official records or statistics of the quantity of tin and terne plates made in the United States between the years 1872 and 1878. There were four different works built for the purpose of manufacturing tin plates, at Wellsville (Ohio), Leechburg, Apollo, and Demmler (Pennsylvania). Of the four establishments only three made tin plates. Sheet iron was made at the Apollo works, and these sheets were tinned by General Charles C. Dodge, of New York City. Tin plates were made at the works in Wellsville, Ohio, in 1873 and 1874, and at the Leechburg works in 1874, 1875, and 1876, and at Demmler up to 1878. In 1872 the price of ordinary I C coke plates, 14 by 20 inches, 112 sheets, was about $14 per box. In October, 1878, the price quoted for the same brand was $5.18 per box. The price steadily declined from 1872 to 1878, when the price was so low that the American manufacturers could not meet it, and the manufacture in the United States was discontinued, and has not been resumed.

Quantity of tin on tin plates.—According to a correspondent of the *British Ironmonger*, the patent rolling processes distribute the tin more evenly over the sheet, and make it thinner than formerly, when the old-fashioned methods were used. It is said, too, that with ordinary coke plates makers seem to vie with each other in making sheets with as little metal on them as is possible. A few years ago but few coke tin plates were made with less than 7 pounds of tin to the box; now we

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(*a*) John Jarrett, in the *Iron Age*, July, 1884.

hear of as little as 2½ pounds of tin to 100 pounds of iron. Another writer in 1884 (*a*) says that the amount of tin used in coating plates is very irregular. The average for a box of I C coke plates, 14 by 20 inches, 112 sheets, weighing 108 pounds, is 3½ pounds; but as low as 2¼ pounds are said to be sometimes used. The same is true for charcoal plates; 5 pounds are considered to be the average weight of tin required to coat a box of tin plates, but as low as 3½ pounds can be used and be accepted.

New method of coating plates.—The *Engineer* describes a new process in tin-plate making, which consists in operating by mechanical means upon the sheets of metal emerging from the bath in which they are coated so as to dispense with "the wash-pot or brushing over," and to yield covered sheets free from scurff and imperfections, and with a better finish than is otherwise given. This is accomplished by causing the sheets as they emerge from the bath to be guided by rollers, covered with molten grease so as to avoid exposure to the air, between washing rollers kept covered with molten metal. The washing rollers do not bear on the sheet, but are so closely adjusted as to wash off the scum and refuse on its surface. On leaving the washing rollers the plate, still passing through a bath of grease to prevent exposure, is passed through finishing rollers to remove the excess of metal, and finally through a pair of improving rollers which bear against each other by means of springs, and thus lightly nipping the sheet between them impart a smooth surface and finish to the metallic covered sheet.

Cleaning plates by gas.—It seems probable that the newly discovered process, at Pittsburgh, of cleaning sheet iron or steel plates by passing a stream of natural gas over and amongst them while at a red heat, packed in a suitable case or box, will be found applicable to the preparation of plates for the tinning bath. It is said that by this process all traces of scale and oxide are removed and that the plates come out of the gas bath perfectly clean and bright. This method certainly promises great advantages over the old method of pickling in acid solutions by which the plates are partly corroded and require careful cleaning to remove acid.

Mild steel plates for tinning.—Until within the past few years charcoal or coke iron bars were considered as the only kind of iron suitable for making the plates for tinning. At present soft steel or ingot-iron bars are largely substituted for charcoal iron. It is claimed that plates made from steel work as well as those made from charcoal iron, and that they are cheaper. Both Siemens-Martin and the Clapp & Griffiths steel have been successfully used. Mr. Ernest Trubshaw (*b*) states that bars for tin plates have been made with considerable success by the Bessemer

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a John Jarrett, in the *Iron Age*, July, 1884.

b "On the Tin Plate Manufacture," a paper read before the Iron and Steel Institute, London, May, 1883.

process, and that he has made plates from bars produced by the Thomas-Gilchrist basic process which have stood the stamping tests fairly well. Some tin-plate manufacturers have erected, and others are erecting, their own steel-making plant. Tinned steel-plates are already well known in the trade.

Terne plates.—The word terne, in French signifying dull, is applied to plates coated with an alloy of tin and lead. This alloy is cheaper than tin, and the product is also cheaper, and is used generally for purposes where the best quality of tinned plates is not required; as, for example, in packing cases for the protection of valuable goods from dampness and water. Experiments are now (1884) making in Pittsburgh in the manufacture of sheet iron plates coated with lead alone, to be used for various purposes where a tin surface is not requisite. Further observations upon terne alloy will be found under the head of "Alloys of Tin."

PRICES.

Tin is a metal which seems well adapted to the purposes of speculators. It is a favorite commodity for speculation, and the course of the market is not to be taken as an index to the demand for the metal for actual consumption. Tin has sold as low as 13 cents and as high as 40 cents per pound. Quotations are generally made in the English pound sterling and fractions, to which for the port of New York the insurance and freight is to be added. As to the actual cost of producing tin in the East Indies by Chinese and convict labor, there is very little reliable information. It is said that at $47 Chinese can make a profit of $10 per picul. When tin falls to $37 per picul the production is still maintained, and it is an unanswered question as to how much lower the price of tin might fall without stopping work. Very little Australian tin reaches New York, but the quantity is increasing. Straits tin and tin from Malacca are preferred in the United States. Banca tin is produced by convict labor.

The price of tin for the year 1884 has been on the whole declining. From quotations of £81 10*s*. for Straits tin in London, in September, it receded to £72 15*s*. in October. This fall in price was attributed to the lessening of the demand for tin in China, consequent upon the war, and the absence of speculation. At the end of the year the price had advanced to £74 10*s*. for spot, and May 1, 1885, to £79 10*s*. Production, however, has continued unabated, there being evidently a wide margin of profit to the producer, even at the lowest prices reached. On the other hand, it is stated that the low prices entailed serious losses upon many of the Cornish mines, and that they have led to great depression.

The following tables show the range of prices for each month for the years 1883 and 1884, in the New York market, not only for block tin but for tin plates of various grades. These statistics have been carefully obtained by Messrs. W. I. Russell & Co., and are printed in the annual number of the *American Metal Market:*

Highest and lowest prices of tin plates and bar tin at New York in 1883 *and* 1884.

Grades.	January.		February.		March.		April.		May.		June.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
Tin plates. Melyn grade, I. C. charcoal:												
1884	6¼	6⅛	6¼	5⅞	6⅛	5⅞	6⅛	5⅞	6.10	5⅞	6.10	5.90
1883	6½	6½	6½	6⅜	6⅜	6.35	6⅜	6.35	6⅜	6⅜	6⅜	6⅜
Tin plates, Allaway's grade, charcoal:												
1884	5½	5.45	5.45	5.35	5⅜	5.30	5⅜	5.30	5⅜	5.30	5.35	5.20
1883	6.15	5.95	5.95	5⅞	5⅞	5.82½	5⅞	5.80	5.80	5¾	5¾	5.70
Tin plates, Dean grade, roofing:												
1884	5.20	5.15	5.15	5	5.05	5	5.05	5	5.05	5	5	5
1883	5½	5.35	5.35	5.30	5¼	5.22½	5.30	5¼	5.35	5.30	5.40	5.32½
Tin plates, B V grade, coke:												
1884	4.85	4⅝	4¾	4.60	4¾	4.60	4.85	4¾	4.80	4.70	4.80	4.70
1883	5.30	5.15	5.15	5.10	5⅛	5	5⅛	5	5⅛	4.10	5.15	5.10
Tin—Straits:												
1884	19¼c.	17.90c	18⅜c.	17¾c.	18⅝c.	17⅜c.	19¼c.	18⅝c.	19⅜c.	18⅝c.	19¾c.	18.55c
1883	21½	21	21	20¾	22	20⅝	21⅝	21	21⅞	21	21½	20¾

Grades.	July.		August.		September.		October.		November.		December.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
Tin plates, Melyn grade, I. C. charcoal:												
1884	6	5¾	5⅞	5¾	5⅞	5¾	5¾	5⅝	5 70	5⅝	5.70	5.65
1883	6⅜	6⅜	6⅜	6¼	6.30	6¼	6.30	6¼	6.30	6¼	6¼	6¼
Tin plates, Allaway's grade, charcoal:												
1884	5¼	5.15	5.35	5.15	5 20	5⅛	5.15	5	5.15	5.05	5.10	5.00
1883	6.70	5.60	5.65	5.60	5⅝	5.55	5.55	5.60	5.60	5½	5.55	5.45
Tin plates, Dean grade, roofing:												
1884	5	4⅞	4.90	4.80	4⅞	4¾	4.70	4.65	4.65	4.60	4.57½	4.50
1883	5.35	5.30	5.35	5¼	5.30	5¼	5¼	5.20	5¼	5.20	5¼	5.15
Tin plates, B V grade, coke:												
1884	4.95	4.80	4.90	4.82½	4.82½	4¾	4¾	4.55	4.70	4.55	4.50	4.50
1883	5.10	5.05	5.07½	5	5⅛	5.02½	5⅛	5.05	5.10	5	5.05	4.85
Tin—Straits:												
1884	18⅞c.	18.70c	19⅜c.	18.15c	18.20c	17.95c	17¾c.	16¼c.	16⅞c	16½c.	16½c.	16.10c
1883	21½	21⅛	21⅜	21	21⅛	21	21¼	20⅛	20⅜	19	19	18½

The following statistics of tin for 1884 as compared with previous years are compiled from Messrs. Wm. I. Russell & Co.'s *Tin Circular*, December 31, 1884: Spot stocks in New York, Boston, and Philadelphia, 1,930 tons; afloat as known, 850 tons. Consumption in the United States in 1884, 10,100 tons, as compared with 12,000 tons in 1883, 10,200 tons in 1882, 8,750 tons in 1881, 11,400 tons in 1880, 7,500 tons in 1879, and 4,800 tons in 1878. Total visible supply and market prices on December 31, as compared with same date in previous years:

New York tin quotations at close of each of the past five years.

	December 31, 1884.	December 31, 1883.	December 31, 1882.	December 31, 1881.	December 31, 1880.
Total spot and afloat ....tons..	2,780	2,801	3,092	3,271	5,441
Quotations:					
Straits ....cents..	16¼	19⅛	21⅛	24½	19¾
Billiton ....do....		19½	21	24¾	19¾
Banca ....do....	19	21½	22	26½	24½
Australian ....do....	16.45	19⅛	21	24½	19¾
English refined ....do....		20	22	24¾	20
English L. and F ....do....	17	20	22	24¾	19½

The following table shows the average prices realized at the Banca and Billiton sales in 1883 and 1884:

Quotations of Banca and Billiton tin in 1883 *and* 1884.

Months.	Banca.		Billiton.	
	1883.	1884.	1883.	1884.
	Florins.	*Florins.*	*Florins.*	*Florins.*
January	56⅝	51⅜		
February			64½	55.34
March	58¼	52⅜		
April			66⅝	58½
May	58	53⅛		
June			64.43	56.22
July	57¼	51⅛		
August			63.79	55¾
September	57⅝	49¾		
October			63¾	49¾
November	53½	46½		
December			56¾	50

IMPORTS AND EXPORTS.

Tin imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	In blocks, bars or pigs, and grain tin.		In plates, sheets, etc.		Total value
	Quantity.	Value.	Quantity.	Value.	
	Cwts.		*Cwts.*		
1867		$1,210,354.02		$6,276,136.78	$7,486,490.80
1868		1,454,327.36		6,893,072.07	8,347,399.43
1869	80,811	1,709,385.00	1,534,324	8,565,432.56	10,274,817.56
1870	81,702	2,042,887.71	1,333,150	7,628,871.51	9.671,759 22
1871	106,595	2,938,409.82	1,556,023	9,490,778.64	12,429,188.46
1872	102,006	3,033,837.45	1,617,627	10,736,906.59	13,770,744.04
1873	130,469	3,938,032.25	1,854,936	15,906,446.82	19,844,479.07
1874	116,442	3,199,807.07	1,553,860	13,322,976.14	16,522,783.21
1875	102,904	2,329,487.96	1,540,600	12,557,630.75	14,887,118.71
1876	93,176	1,816.506.00	1,767,210	10,226,802.87	12,043,308.87
1877	98,209	1,783,763.00	1,984,893	9,818,069.69	11,601,834.69
1878	128,849	2,167,350.00	2,166,489	9,893,639.61	12,060,989.61
1879	142,927	2,301,944.00	2,487,007	10,248,720.34	12,550,664.34
1880	290,007	6,153,005.68	3,298,534	16,524,590.19	22,677,595.87
1881	171,146	3,971,756.67	3,366,720	14,641,057.87	18.612,814.54
1882	197,544	5,204,251.68	3,926,311	16,550,834.64	21,755,086.32
1883	237,348	6,106,250.37	4,051,108	16,688,276.67	22,794,527.04
1884	*a*26,031,992	5,429,184.01	*a*527,881,321	18,931,072.70	24,360,256.71

a Pounds.

Value of tin manufactures exported from the United States. (*a*)

Fiscal years ending September 30, until 1842, and June 30 since.	Value.	Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1826	$4, 515	1846	$8, 902	1866	$79, 461
1827	2, 967	1847	6, 363	1867	40, 642
1828	5, 049	1848	12, 353	1868	27, 110
1829	1, 757	1849	13, 143	1869	18, 994
1830	4, 497	1850	13, 590	1870	46, 007
1831	3, 909	1851	27, 823	1871	70, 366
1832	3, 157	1852	23, 420	1872	67, 241
1833	2, 928	1853	22, 988	1873	69, 865
1834	2, 230	1854	30, 698	1874	62, 973
1835	2, 545	1855	14, 279	1875	48, 194
1836	5, 604	1856	13, 610	1876	48. 144
1837	10, 892	1857	5, 622	1877	87, 057
1838	10, 179	1858	24, 186	1878	116, 274
1839	19, 981	1859	39, 289	1879	103, 467
1840	7, 501	1860	39, 064	1880	144, 185
1841	3, 751	1861	30, 229	1881	498, 524
1842	5, 682	1862	62, 286	1882	198, 608
1843 (nine months)	5, 026	1863	41, 558	1883	191, 947
1844	6, 421	1864	46, 968	1884	166, 819
1845	10, 114	1865	106, 244		

a Classed as "tin *and* manufactures of" from 1851.

Oxide of tin imported and entered for consumption in the United States, 1869 *to* 1883, *inclusive.* (*b*)

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$1, 524	1877	$1, 886
1870	2, 958	1878	929
1871	3, 061	1879	2, 138
1872	18, 414	1880	2. 849
1873	1, 475	1881	2, 510
1874	4, 962	1882	920
1875	14, 838	1883	4
1876	3, 484		

b Not enumerated in 1884.

ANTIMONY.

BY W. P. BLAKE.

Antimony is a tin-white volatile metal, which at ordinary temperatures is very brittle and may be reduced to powder. Its hardness is a little greater than that of calcite, and its specific gravity is about 6.5. It occurs sparingly in the native or metallic state, but the principal and commercial source of the metal is the sulphide, known as gray antimony or stibnite. This compound when pure is composed of antimony, 71.8; sulphur, 28.2. This ore is softer than the metal and has a lower specific gravity (4.5 to 4.6). Like the metal, it can be pulverized to a dense black powder, which is used for a variety of purposes. Another ore of antimony, which occurs sparingly and generally as a result of the oxidation of the sulphide, is known as white antimony or valentinite. There is also red antimony, or kermesite, known in chemistry as kermes. But stibnite is the most common and the best known ore.

ANTIMONY LOCALITIES IN THE UNITED STATES.

California.—The sulphuret of antimony vein at San Emigdio, in Kern county, California, was described in 1853 and 1855.(*a*) This was the first discovery of any antimony deposit of commercial importance in the United States. Some rude attempts had been made before that time to work the ore for silver. Since then but little has been done beyond the shipment of some of the ores to San Francisco by way of San Buenaventura, and by rail since the construction of the railway. The vein has also been opened at many distant points by short tunnels and pits, and a series of claims along the line of the lode have been patented. These claims are owned by Mr. S. Bouschy, who has devoted many years to the development of this property. The vein consists of quartz and gray antimony, and traverses a granitic rock in a direction nearly northwest and southeast, with a dip to the west of 64°. It cuts through a granitic mountain, outcropping on both sides, so that it may be followed up one side and down upon the other. The lower openings are at an elevation of about 5,000 feet and the upper at about 5,800 feet, at the summit. It is thus favorably situated for mining and the supply of ore seems to be enormous. The width of the vein varies in different places from a few inches to many feet. The vein matter is

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a W. P. Blake, United States Pacific Railroad Explorations and Surveys, Vol. 5, pages 291–295.

in places 20 or 30 feet wide. The distance horizontally through the mountain from one tunnel to the other on the opposite slope is estimated to be not less than 4,500 to 5,000 feet, and there is little doubt that the vein may be followed for the whole distance. The quartz of the vein is said to contain from $16 to $18 in value of gold per ton. It is possible that the stibnite is also auriferous. The property has not yet been extensively worked. Mr. Bouschy has made some attempts, with a limited amount of capital, to smelt the ore, but in 1883 the furnace buildings took fire and were destroyed. Work was resumed in the year 1884. Mr. S. Bouschy, Alexander B. and George Chaffey, and G. H. Howland are reducing the ore to matte, or crude antimony, with success. Ten iron pots are used, in each of which 100 pounds of antimony ore are treated at one heat. Some fine samples of metal produced at this mine were exhibited at the rooms of the Board of Trade in Los Angeles. (*a*)

There are several other localities in the State of California, some of which give promise of capacity to supply ore in commercial quantities. The Stayton mine, 3 miles south of Alta, in San Benito county, and the Alta mine, 1 mile from Clark's rancho and 14 from Hollister, have yielded some ore, which has been sent to San Francisco and sold. At the Alta claim there is a distinctly formed vein traversing a trachytic or plutonic rock. It is from an inch or less to 24 inches thick, and has well defined kaolinized walls. The gangue or veinstone is quartz. In some places there are masses of ore 6 inches thick, and solid stibnite. From 6 to 15 inches of ore, more or less mixed with the quartz gangue, is common. The mine is opened by a tunnel 200 feet long and a winze 100 feet deep. This vein can be traced for 150 feet or more up the hill. It is favorably situated for mining and should furnish a large amount of ore of good quality. The tunnel in 1881 was 150 feet long and had a considerable amount of ore standing between it and the surface of the hill. Mr. Samuel Ambrose is the chief owner and superintendent. The mines have not been worked for two or three years past.

Antimony ore (stibnite) has been found at several places in California associated with cinnabar, some specimens being nearly half stibnite and half cinnabarite.

The ore has been found also, according to H. G. Hanks, in washed bowlders, at the Centennial mine, San Bernardino county; Pacheco pass, Monterey county; Mammoth mine, Mineral King district, Tulare county; in the Panamint mountains, Inyo county, in large veins; at the head of Bloody cañon, Mono county, with chalcedony and cinnabar; and at the Lake quicksilver mine, Lake county. A new discovery of a vein of antimony ore is reported in Kern county, about 45 miles east of Bakersfield. The vein is said to be large.

Nevada.—There are numerous localities in this State where stibnite has been found, either in lodes by itself or in association with other

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a Report of H. G. Hanks, State mineralogist of California, for the year ending May 15, 1884.

minerals. One of the best-known occurrences is about 12 miles south of Battle Mountain station, on the Central Pacific road, in Humboldt county. The ore is described as found in two parallel veins about 100 feet apart and standing nearly vertical. Some of the ore has been shipped to San Francisco and worked, but of late the mines have been idle. Antimony ore also is found in Relief district, Humboldt county, about 18 miles east of Lovelock's station, on the Central Pacific Railroad. It is stibnite in a gangue of quartz, and has yielded considerable ore from the croppings downward to a depth of a few feet. This ore might be concentrated by liquation so as to separate it from the quartz, with which it is so much blended that it cannot be separated by hand-sorting.

Utah.—Remarkable deposits of stibnite, with some valentinite and senarmontite, the result of the oxidation of the stibnite, are found in the sandstone formation of southern Utah, in bedded masses, following the stratification of the nearly horizontal beds. The locality is in Iron county, upon Coyote creek, a clear-flowing stream of water, which, rising in the bluffs of the "rim of the basin," north of the Great Cañon of the Colorado river, flows westward into the Sevier river. The general elevation of the region is 6,500 feet or more. The rocks are soft, gray, granular sandstones, underlaid by a thin bed of limestone and a conglomerate of water-worn bowlders of quartz forming the base of the bluffs along the eroded valley of the creek. The antimony ore occurs just above the junction of the sandstone with the limestone and the conglomerate. In some places the ore has been found in the conglomerate, penetrating irregularly between the bowlders. It is usually in the sandstone and is not accompanied by any veinstone or gangue or any evidences of a vein formation. It is bedded in the midst of a sand rock parallel with the stratification. The thickness of these layers of ore varies at different points from a fraction of an inch to 20 to 30 inches, so far as observed. In general there is only one bed or layer, but there are evidences of the existence of two or more layers in some parts of the area over which the ore has been traced. Large quantities of ore were found in outlying masses on the surface or slopes of the sandstone hills, having become weathered out and detached by the gradual wearing away of the strata where cut through by the main valley or by the lateral valleys. Some of these detached masses weighed several tons, and could not be moved without being blasted into fragments. One mass of nearly pure stibnite weighed about 3,000 pounds, and was sent to Salt Lake and thence to New York. This mass, like most of the ore found in the sandstone, has a very strongly defined radial structure, the crystallization being in close aggregations of long, needle-like fibers or prisms, which are divergent from central points or nuclei, giving a stellate appearance to the masses, and particularly to the smaller aggregations, some of which are only a few inches in breadth. In the large masses the radial fibers are sometimes 18 inches long, and form dense aggregations of pure ore 8 to

15 inches thick at the large end, tapering to a point at the other end. The layers do not form continuous sheets following the sandstone beds, but consist of disconnected aggregations or bunches here and there, though much more numerous in some places than in others. The ore appears to have formed or crystallized from independent disconnected points along the particular stratum or horizon of sandstone. The result of this irregular aggregation is that in some parts of the formation the ore is much more abundant than in other parts, as has been shown by sinking shafts to the horizon of the ore. All the phenomena indicate that the stibnite crystallized in the sandstone after the deposition of the rock, and that it is the result of the percolation of antimonial solutions, which either descending or ascending, probably descending, found in the particular sandstone bed the conditions which were favorable to their crystallization. It is certain that the ore was formed in the beds after their deposition. The presence in the vicinity of the deposits of extended beds of lava overlying and capping the sandstone strata suggests the possibility that these lava outflows, during their cooling and subsequently, were the source of the antimonial emanations or solutions.

The Utah mines were opened in 1880, and a company was formed in Salt Lake City to work them, under the title of the Utah Antimony Mining and Smelting Company. In 1881 the property passed into the possession of a new incorporation in New York, called the American Antimony Company. Some metal was made and sold in the market, and was considered excellent in quality, but owing to the great cost of transportation and the low price of the metal the production was not found to be profitable, and work was suspended and has not been resumed.

FOREIGN SOURCES OF ANTIMONY.

New Brunswick.—There are several localities of stibnite in this province, and some have been extensively worked. In Prince William parish, county of York, about 20 miles west of Fredericton, a lode was discovered in the year 1860 and has been worked since at intervals. A company, called the Prince William, was formed, and a quantity of ore was shipped to England. About $150,000 was expended in mining and putting up reduction works, but this was considered as lost, and work was suspended until 1860, when a new company, known as the Brunswick Antimony Company, was formed in Boston and acquired this property, and also the Hibbard, Lake George, and adjacent properties. The rock in which these veins occur is described as a thick argillite slate. The gangue is quartz and calcite, and besides stibnite large pocket-like masses of native antimony are found, some of them yielding over a ton of the metal. This metallic antimony is remarkably pure and is associated with stibnite, valentinite, and kermesite. The masses are in a rounded and elongated form, often 12 inches broad, and also in radiated aggregations of blade-like crystals, some of them 2 inches long and one-eighth of an inch wide. The stibnite also occurs crystallized in divergent blades and in masses without crystallization

Nova Scotia.—The West Gore antimony mines are situated in Rawdon township, Hants county, about 15 miles from stations on either the Intercolonial or Windsor and Annapolis railroad. The vein is reported to average 13 inches of metal or ore and to be opened by two shafts, 120 feet apart and 110 feet deep. A shipment of 100 tons to England averaged 60 per cent. antimony. Six hundred tons of antimony ore were exported in 1884.

Sonora, Mexico.—A few years ago some very remarkable croppings of white oxide of antimony ("white antimony") were found a short distance south of the Arizona line and near the Gulf of California. It was massive and nearly pure, associated with quartz and silver ore, and yielded excellent metal. A company was formed to work it, and reduction works were established in Oakland. A supply of the ore was procured and a few hundred pounds of metal was produced, but the many difficulties encountered and the variable percentage of the ore, together with the costs of mining and transportation, led to the abandonment of the enterprise. As the depth of the workings on the croppings increased the amount of silver increased, until it seemed probable that the antimony had been derived from the decomposition of an antimonial ore of silver. Some of the blocks of ore sent to San Francisco had thin films of chloride of silver in the seams of the rock. The quantity diminished in depth as the oxide was gradually replaced by the unoxidized ores.

France.—In the year 1880 the production of antimony ore amounted to 1,214 tons, valued at 243,440 francs ($48,688). A portion, at least, of the ore is obtained from Algeria and Italy. In the year 1882 the production was 178 metric tons.

Spain.—The official statistics of the mining industry in Spain show a production of 30 tons of antimony ore, valued at 6,450 pesetas ($1,290), in the year 1882.

Portugal.—Antimony lodes occur in three different regions and in as many distinct geological formations. In Evoca district the ore is found in a quartz lode, between the Palæozoic beds and granite. In Oporto district it is found in the neighborhood of Valongo, Parades, and Gondomar, in bed-like lodes in Silurian rocks. In the district of Faro there are two distinct lodes, only one of which is worked. These lodes are in the slates of the culm formation. The production of antimony in Portugal for the year 1881 is stated as 866 long tons. In 1883 the ore was obtained from fourteen mines, and lead with antimony was raised from three mines.

Prussia.—Stibnite occurs in Rhenish Prussia, between Wintrop and Ventrop, in bedded deposits in the limestone and shales of Devonian age. The antimony is most abundant in the midst of the beds and penetrates cracks and fissures. Eleven layers of antimony-bearing strata had been opened up as early as the year 1833 in the Caspari mine. The heavier and larger masses of stibnite sometimes include fragments of the inclosing rock. At the Hoffnung mine the Devonian slates dip at an angle of 45°; and the antimony ore, which is associated with iron pyrites and brown spar, occurs in a band or belt of the rock as much as 120 feet in width. This, in 1827, had been opened upon in the direction of the strike for about 560 feet. The stibnite is said to be found partly in true veins as well as between the planes of stratification. The total production of antimony ore in the German Empire, inclusive of Luxembourg, during the year 1881, according to the official statistics, was 77 tons, valued at 16,702 marks ($4,175).

Austria.—The production in the year 1882 was 509 tons, valued at 22,232 gulden ($11,115).

Bohemia.—The production of antimony ore in 1881 was 187 tons. In 1873 the Milleschau Antimony Company made an exhibition of their antimony products at Vienna. Their mines are near the Moldau river, and are upon seven lodes in granite from 1 inch to 12 feet thick. One of the specimens shown was a solid mass of gray antimony ore weighing 2,300 pounds. At that time the company employed three hundred men. Other ores were shown from mines near Plan, in Bohemia. The lodes are said to be 12 feet wide, and to intersect the mica-schists of the district.

Hungary.—The production in 1881 was 767 tons, valued at 84,728 florins ($42,360). In 1871 the production was about 126 tons.

Italy.—In the year 1880 the production was 402 tons, valued at 80,400 lire ($16,080). Red antimony (kermesite) is stated to be mined in Tuscany and to be smelted at Marseilles, France.

Algeria.—Stibnite and oxide of antimony (white antimony ore or senarmontite) derived from the alteration of the sulphide, are found in considerable quantities at El Haminat, about 43 miles from Constantine, and at Sousa. Specimens from these localities were shown at the International Exhibition in Paris in 1878, and at Vienna in 1873.

Victoria.—The production of antimony ore in this British colony, in the year 1880, amounted to 333 tons 17 cwts., of which 272 tons 17 cwts. were smelted in the colony, yielding 178 tons 10 cwts. of regulus. In 1882 376 tons of antimony ore were mined, and were valued at £2,632. The ore occurs in many places, and is frequently auriferous. At Sunbury a lode from 3 to 18 inches in thickness, consisting chiefly of quartz and stibnite, traverses Silurian strata, and contains about 2 ounces of gold to the ton. At Whroo the antimony ore occurs in concretionary masses in concentric layers around a central nucleus of sulphide of antimony. The outer oxidized layers contain native gold, sometimes in grains as large as a pea. The occurrence of auriferous antimony ores appears to be common, the association being observed also in California, and it was mentioned in metallurgical treatises as early as 1827. Gold occurs also at the Costerfield mines. According to the *Mining and Scientific Press* of September 13, 1884, the process adopted by the Costerfield Company for treating these ores, consisting of sulphide and brown and white oxides of antimony, is as follows: The portion of the ore free from quartz is picked out and set aside for smelting, the remainder being crushed to extract the gold. The tailings are then conveyed to heaps and prepared for smelting by a process of puddling. A sluice-box is fed with tailings, which pass on to a triangular tray, forming an incline flume, so arranged as to cause the water and tailings to flow over it in a broad, shallow stream into an oblong receiving pit. The purest antimony ore, from its greater specific gravity, settles in the pit at the end nearest the tray. As the sediment recedes from this end it gradually becomes mixed with an increasing proportion of sand; but much of the latter is carried away in the overflow of water from the pit.

On cleaning out the receiving pit, that portion of its contents containing quartz sand is returned to the heaps, to be again passed through the buddle, and the pure ore is collected in bags and sent to the boiler-house to be dried. It is then placed in a smelting furnace, with equal proportions of uncrushed ore, and reduced to crude antimony, the slag and cinder resulting from this process being further treated by roasting or calcining in a reverberatory furnace to liberate the oxide, which passes off in fumes from the furnaces into the oxide flue; and as the fumes cool on their passage to the smokestack, the oxide is deposited in chambers constructed in the flue to receive it. The residue from the reverberatory furnace is afterwards crushed to extract any gold it may contain. The gold obtained from the mineral defrays the whole of the company's working expenses, and the yield of crude antimony and oxide is clear profit. The ore yields about 45 per cent. of crude antimony.

The process adopted for treating auriferous ores containing antimony sulphide, by fusing the sulphide with a portion of metallic antimony, and using the same metal with fresh charges of the ore, until it becomes rich in gold, and then separating the two metals by the oxidation of the antimony, while suitable for rich antimony ores, will not answer for those containing less of the sulphide, as they are too siliceous to fuse.

According to Locke, Mr. Cosmo Newberry has introduced the following method for treating such ores, which may also contain gold, silver, nickel, cobalt, sulphur, and arsenic. The uncrushed ores are placed in a kiln or furnace with a quantity of salt, sufficient to produce the amount of chlorine necessary to get rid of the sulphur, antimony, and arsenic. As soon as the calcination commences a supply of steam or aqueous vapor is conducted to the bottom of the kiln or into the furnace, in such quantities as to keep the whole mass saturated. That it is so saturated is ascertainable by holding a condensing surface, such as a piece of cold iron, over the calcining mass. If the saturation is being effected the surface soon becomes damp. The saturation is continued until there are neither antimonial nor arsenical fumes, nor the smell of sulphurous acid or sulphureted hydrogen. The process is then completed and the charge is drawn; it is ready for any further treatment for extracting the precious metal. A peculiar condenser for facilitating the solidification of the metallic vapors given off in these roasting processes has been perfected by the introduction of the process described.

New South Wales.—Considerable quantities of antimony ore are now obtained from New South Wales. It has been discovered in many localities in the Macleay district, at Hargrave's Falls, and in the neighborhood of Aberfoil. In the Bathurst district stibnite has been found in loose blocks. The close association of antimony ore and gold has been noted in New South Wales by Mr. C. S. Wilkinson. He reports auriferous antimony lodes at Hill Grove, in rocks which are regarded as metamorphosed Devonian. The lode consists of a network of quartz veins accompanying a granitic dike. The ore is the sulphide (stibnite) and also the oxide, in bunches in which gold is sometimes distinctly visible. At a mine near Armadale a vein from 10 to 15 inches in width is said to yield 50 per cent. of antimony and 22 pennyweights of gold per ton.

According to the annual report of the mining department, Sydney, New South Wales, the quantity of antimony produced in the colony was as follows:

Production of antimony in New South Wales.

Years.	Quantity.		Value.
	Tons	*cwts.*	
1871	31	0	£560
1872	0	13	5
1873	27	12	210
1874	12	15	122
1875	142	0	5,000
1876	40	0	140
1877	69	12	1,131
1878	64	0	1,964
1879	76	16	1,046
1880	99	19	1,652
1881	539	24	17,346
	1,104	11	29,176

Exports of antimony, antimony ore, and regulus from New South Wales.

	Ore.		Regulus.	Metal.		Value.
	Long tons.	*cwts.*	*Long tons.*	*Long tons.*	*cwts.*	
Prior to 1883	1,696	1	142	334	8¼	£45,908
1883	357	2		18	9	5,555
Total	2,053	3	142	352	17¼	51,463

There were no returns previous to 1871. Later statistics show that the production for 1882 was 23 tons of antimony and 1,046 tons of antimony ore.

Japan.—In the year 1874 a small quantity of antimony was produced from four mines in this country. It occurs on the island of Amakusa, in small and irregular veins, and in seams from 1 inch to 1 foot in thickness. Numerous magnificent crystallizations of stibnite have recently been obtained in Japan from the mines of antimony on the island of Shikoku, in the province of Iyo. The mineralogical collection at Yale College and several other collections have of late been enriched by specimens from this locality. The great size and perfection of form of the crystals is remarkable. They are prisms with brilliant lateral and terminal planes. These prisms are sometimes over 20 inches in length. The finest group of crystals in the Yale museum has a length of 11 inches and a height of 10½ inches. These remarkably fine crystalizations have been described in detail by Prof. E. S. Dana (*a*), who identifies forty planes new to science in this species, making eighty-five planes in all now known and described.

Borneo.—This country has been a well-known source of antimony for many years. The ore was discovered there in 1825. In 1880 antimony to the value of $72,516 was exported. The principal mine is at Bidi, in Sarawak. From the report of acting Consul-General Thacher for 1883 it appears that the export of antimony, which in 1881 amounted to 1,856 tons, and in 1882 to 1,440 tons, fell in 1883 to 1,361 tons; and there can be no doubt that this result is in a great measure to be accounted for by a falling off in the supply, as old workings have been exhausted. Efforts are being made to prospect more thoroughly the district of Upper Sarawak, where alone antimony has hitherto been found in quantity.

Tonquin.—Antimony ores are reported as occurring in this country, but no definite information is accessible.

MISCELLANEOUS.

Extraction.—The extraction of antimony from its ores is attended with some difficulties, owing to its volatility and affinity for oxygen. If the sulphide is much mixed with veinstone, such as quartz, it is subjected to the preliminary process of liquation, by which the fused sulphide flows away, leaving the rock behind. The sulphur is extracted either by heating with iron, alkalies, and charcoal, leaving a regulus of metal, or by oxidation, leaving the antimony in the condition of teroxide, which is afterwards reduced with charcoal and alkalies in crucibles. The metal sinks to the bottom, and the overlying residue is known as crocus of antimony.

The chief centers of the extraction of antimony are in Hungary, Germany, France, and Great Britain. The ores of antimony were formerly mined in Great Britain, but ore now is imported from Singapore, Borneo, and other localities. Much of it is sent as ballast at very low rates of freight. The ores which are smelted near Marseilles, in France, are obtained from Algeria and Tuscany.

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a *American Journal of Science*, Vol. XXVI., page 214.

Extraction of antimony in the United States.—Up to the year 1883 but little metallic antimony had been produced in the United States. A few cakes of excellent metal had been made in Oakland, California, from the white antimony ore of Sonora, but owing to various difficulties the enterprise was soon abandoned, and the works have since been burned down.

Works in San Francisco for the reduction of ores of antimony and the production of the commercial metal were equipped by Messrs. Starr & Mathison, and produced some excellent "star" antimony, equal to any imported. The difficulty of securing a regular supply of ore of a high grade at remunerative figures is reported to have caused the closing of the works in 1883.

At the San Emigdio mine, in Kern county, California, Mr. Bouschy has erected furnaces for the production of regulus, and operations were resumed in the summer of 1884, and a small quantity of metal is made at a profit.

A considerable quantity of hard lead, containing antimony, is obtained in the lead-smelting operations of the Castle Dome Mining and Smelting Company, at Melrose, Alameda county, California, and has been utilized in the manufacture of antimonal alloys for several years past. The same is true of other lead-smelting works.

A large quantity of antimonial lead is produced at the works in Kansas City, Missouri, and it is utilized by the Wadsworth Metal and Manufacturing Company for the manufacture of antimonial alloys, such as various grades of Babbitt metal; electrotype, stereotype, and white metals, solders, etc. This source of antimony, although in alloy with lead, materially affects the market for the pure metal, inasmuch as a large part of the demand for the ordinary crude alloys of antimony and lead is supplied by it, and without the cost of a preliminary separation.

The production of antimony from the Utah ore has already been mentioned.

Uses of antimony.—Antimony is an important constituent of many useful alloys, generally imparting hardness to the softer metals. With lead it forms type metal, the antimony not only giving hardness but causing the expansion of the alloy at the moment of cooling, whereby the casting is sharper and better formed in the mold. The amount of antimony in type metal is generally from 17 to 20 per cent., though type metal is sometimes made of 1 part of antimony and 4 parts of lead. For stereotype plates a small quantity of tin is added, from one-eightieth to one-fiftieth part.

Britannia metal contains from 10 to 16 parts of antimony and 81 of tin. Babbitt metal, an anti-friction alloy for the journal boxes or bearings of machinery, contains 8.3 per cent of antimony. Pewter contains about 7 per cent.

With tin antimony forms white brittle alloys. The addition of a very small quantity of tin promotes the crystallization of antimony and gives larger crystals. Added to iron in the proportion of 70 parts of antimony and 30 of iron it forms a hard, brilliant, and fusible compound. It renders gold and silver brittle. Its effects on copper are remarkable and injurious. It is said that the one-thousandth part of antimony will destroy the good qualities of the copper, and that one four-thousandth part will reduce the quality of "best selected" to "tough ingot" grade.

Compounds of antimony are extensively used in medicinal preparations, tartar emetic being one of the most important, and in the manufacture of pigments. The pulverized stibnite is found to be an excellent material for the vulcanization of rubber.

Estimation of antimony.—A method of quickly making commercial determinations of antimony present in ores, alloys, or slags is described by Mr. G. T. Dougherty. (*a*) The substance is first reduced to a button by fusion. If in an oxidized state, it is melted with charcoal and red argol; if combined with sulphur, it is decomposed by fusion with equal parts of potassium cyanide and sodium carbonate. Ten grams is the most convenient quantity to use. The weighed button is then cut into small pieces, placed in a porcelain dish, and digested at a boiling heat in a mixture of equal parts of nitric acid and water, until the solution has nearly evaporated and the lead is dissolved, leaving the antimony as a white, insoluble precipitate of antimony tetroxide (Sb_2O_4), which is separated by filtration from the diluted solution, and is dried and weighed. In a button containing lead and antimony only, the quantity of lead is ascertained by deducting the weight of the antimony, or it may be determined from the filtrate as sulphate of lead.

Imports and prices.—The importation of antimony at the port of New York amounted to 3,406 casks in 1883, and 3,044 in 1884. The general range of price for the same year was from 10 to 11¼ cents per pound for Cookson's, and from 8.85 to 10.25 cents for Hallett's. At the end of the month of October, 1884, antimony was selling in Liverpool at £41 to £42 per ton, and in December, 1884, at £40 per ton. In the month of April, 1885, and on the 1st of May, it was quoted at £38 to £38 10*s*. In the New York market the price had fallen to 9¾ cents for Cookson's.

The shipments of metallic antimony from California amounted in 1882 to a little over 30 tons. In 1883 shipments fell off, while in 1884 they were again slightly increased, some small lots of ore having in the mean time been exported.

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a Engineering and Mining Journal, Vol. XXXVIII., page 345, November 22, 1884.

Antimony and antimony ore imported and entered for consumption in the United States, 1867 to 1884 inclusive.

Fiscal years ending June 30—	Crude and regulus.		Ore.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1867	....	$63,919	....	....	$63,919
1868	1,033,336	83,822	....	....	83,822
1869	1,345,921	129,918	....	....	129,918
1870	1,227,429	164,179	....	....	164,179
1871	1,015,039	148,264	....	$2,324	150,588
1872	1,933,306	237,536	....	3,031	230,567
1873	1,166,321	184,498	....	2,941	187,439
1874	1,253,814	148,409	....	203	148,612
1875	1,238,223	131,360	6,460	609	131,969
1876	946,809	119,441	8,321	700	120,141
1877	1,115,124	135,317	20,001	2,314	137,631
1878	1,256,624	130,950	20,351	1,259	132,209
1879	1,380,212	143,099	34,542	2,341	145,440
1880	2,019,389	265,773	25,150	2,349	268,122
1881	1,808,945	253,954	841,730	18,199	272,153
1882	2,525,838	294,234	1,114,699	18,019	312,253
1883	3,064,050	286,892	697,244	11,254	298,146
1884	*a*1,779,337	150,435	231,360	6,489	156,924

a Classed as regulus only.

The bonded stocks of antimony at the port of New York on the first days of each month in 1884, as compared with the same dates in 1883, are shown in the following table, compiled from the *American Metal Market*, January 3, 1885:

Months.	1884.	1883.	Months.	1884.	1883.
	Casks.	*Casks.*		*Casks.*	*Casks.*
January	128	143	July	57	118
February	128	125	August	32	114
March	128	125	September	32	114
April	103	133	October	32	118
May	28	107	November	32	124
June	32	107	December	32	129

Opening, closing, highest, and lowest prices of antimony of Cookson's brand and Hallett's brand in each month of the year 1884 *compared with the same month in the year* 1883.(*b*)

[Cents per pound.]

Months.	Cookson's.		Hallett's.	
	1884.	1883.	1884.	1883.
January:				
Opening	11¼	11¼	10¼	10½
Highest	12	11¼	11	10½
Lowest	11.15	11	10.20	10
Closing	11¾	11	11	10⅛
February:				
Opening	11¾	11	11	10⅛
Highest	11⅞	11	11⅜	10⅛
Lowest	11½	10⅞	11	9⅞
Closing	11¾	10⅞	11¼	9⅞
March:				
Opening	11¾	10¾	11¼	9⅞
Highest	11¾	10¾	11¼	9⅞
Lowest	11⅜	10.70	10¾	9¾
Closing	11⅜	10.70	10⅞	9¾

b From the *American Metal Market*, January 3, 1885.

Opening, closing, highest, and lowest prices of antimony, &c.—Continued.

Months.	Cookson's.		Hallett's.	
	1884.	1883.	1884.	1883.
April:				
Opening	11¼	10⅝	10¾	9.70
Highest	11¼	10¾	10¾	9¾
Lowest	11	10⅝	10⅝	9.70
Closing	11	10.70	10⅝	9¾
May:				
Opening	11	10.70	10⅝	9.70
Highest	11¼	10.70	19⅝	9.70
Lowest	11	10⅝	10½	9⅝
Closing	11	10⅝	10½	9⅝
June:				
Opening	11	10⅝	10½	9⅝
Highest	11	10⅜	10½	9⅝
Lowest	10⅞	10½	10.30	9½
Closing	10⅞	10½	10.30	9½
July:				
Opening	10.85	10⅜	10.30	9½
Highest	10.85	10⅜	10.30	9½
Lowest	10¾	10¼	10¼	9⅜
Closing	10¾	10¼	10¼	9⅜
August:				
Opening	10¾	10¼	10¼	9¼
Highest	10¾	10¼	10¼	9⅜
Lowest	10½	10¼	10⅛	9⅛
Closing	10½	10¼	10⅛	9⅛
September:				
Opening	10½	10¼	10⅛	9⅛
Highest	10½	10¼	10⅛	9⅛
Lowest	10⅜	10	10	9
Closing	10⅜	10⅛	10	9
October:				
Opening	10.35	10⅛	9.95	9
Highest	10.35	10⅛	9.95	9
Lowest	10¼	9⅞	9⅞	8.85
Closing	10¼	10	9⅞	9
November:				
Opening	10⅜	10	10⅛	9
Highest	10⅝	11	10⅜	10¼
Lowest	10¼	10	9⅞	9
Closing	10⅝	10¾	10⅜	10¼
December:				
Opening	10½	11	10¼	10¼
Highest	11	11¼	10¼	10¼
Lowest	10½	11	10	10⅛
Closing	10¾	11¼	10⅓	10¼

Exports.—The statistics of exports of antimony and antimonial ores are very imperfect, as both are usually classed under other heads. The exports of ore, as recorded, range from a few hundred dollars' worth to $13,619 in the fiscal year 1882. In the fiscal year 1883 the exports reported were valued at $3,500.

BISMUTH.

Ores.—The most important ore of bismuth is the native metal, which is found associated with gold, silver, cobalt, and nickel ores. It has been identified in Monroe county, New York; at Haddam, Connecticut, and in Virginia. Tetradymite, a telluride of bismuth, containing from 60 to 80 per cent. bismuth, is found in the gold belt of Virginia and North Carolina, and in Arizona. Bismuth-silver is a native alloy of bismuth and silver, containing varying proportions of the two metals, ranging from 27 per cent. bismuth and 15 silver to 10 bismuth and 60 silver, with irregular amounts of copper, lead, iron, sulphur, arsenic, etc. Bismuthinite is a sulphide, normally containing 81.6 per cent. bismuth and 18.4 sulphur. Bismuth ocher is an oxide, containing about 90 per cent. metallic bismuth. Bismutite, a hydrated carbonate, containing 90 per cent. bismuth, 6.56 carbonic acid, and 3.44 water, has been found in South Carolina. Besides these minerals rare silicates of bismuth have been observed.

Occurrence in the United States.—Several veins carrying bismuth have been found at a point 12 miles west of Beaver City, Utah. They occur in a magnesian limestone, and vary from 1 to 9 feet in thickness. The entire vein matter is said to assay from 1 to 6 per cent. metal, the ore being of such low grade that it would require to be concentrated. As it is free from arsenic and antimony it is thought that it can be handled with profit notwithstanding its low grade. The ore is native bismuth with pyrite and a little galena, carrying some silver, in a quartz gangue. One of the mines, the Bismuth, in Granite district, Beaver county, discovered in 1865, shipped a little ore in 1871, which is said to have carried 7 per cent. metal. The developments are small, consisting of a number of short prospecting shafts and tunnels.

In Colorado a number of occurrences are reported, particularly in Hinsdale, Boulder, Jefferson, La Plata, and San Juan counties. In the ores of the last-named county Mr. T. B. Comstock has identified bismuthinite (sulphide of bismuth), wittichenite (copper and bismuth sulphide, rich in silver), and aciculite or aikinite (lead, copper, and bismuth sulphide) in beautiful crystals. A small specimen from the Gladiator mine, Lake City district, Hinsdale county, showed 81 per cent. bismuth, carrying silver at the rate of 1,544 ounces per ton. The Bismuth Queen mine, near Golden, has also produced some very rich bismutite and bismuthinite ore.

A grayish green, impure oxide of bismuth, averaging from 8 to 10 per cent. bismuth, has been found near Tucson, Arizona, and it is thought to be present in considerable quantity. A piece of bismuth ore was also found in gold washings near Phœnix. Tetradymite (telluride of bismuth) has been identified in this Territory.

A specimen of bismuth ore, found by miners while washing gold-bearing gravel on Big Pine creek, Inyo county, California, is now in the State museum. Bismuth has also been reported as occurring in remarkable purity on the flank of Mount Vostovia, Alaska. The occurrences in Connecticut, New York, Virginia, North Carolina, and South Carolina, already noted, are of mineralogical interest merely.

There is no commercial production of bismuth in the United States, though it is possible that the occurrences of its ores, especially in Colorado and Utah, may be utilized to a limited extent in connection with the smelting of silver ores. At present prices a large deposit of workable bismuth ore would be a valuable find, and it would seem profitable to treat the small quantities of rich bismuth ore hitherto worked for the silver contents alone, for the bismuth as well. There are no reduction works in this country designed for the extraction of bismuth, which, however, is a simple metallurgical process. The small lots of metal produced hitherto have been obtained in experiments.

Sources.—The supplies of bismuth are drawn principally from the mines of Saxony, Hungary, Baden, Cornwall, and Australia. The ores also occur in South America, especially in Bolivia and Chili. The total production is small.

Price.—During 1883 and 1884 the price has been held at about $2 per pound, though on a flurry in the London market it dropped to $1.05, from which figure it almost immediately recovered to $2.

Uses.—Metallic bismuth is used in making fusible alloys, such as soft solder and plugs for safety valves and automatic fire extinguishers; in stereotype metal, for molds; as an amalgam for silvering glass globes, and it has been tried in the molten state as a bath for tempering steel. The subnitrate is used under the name of pearl white in enamels, in porcelain, in optical glass, in medicine, and as a cosmetic. The carbonate is employed to a small extent in medicine. The nitrate is used as a mordant.

Imports.—The following table gives the imports of bismuth during recent years, with their foreign valuations, from which it will be seen that the consumption in this country is very small. Bismuth is on the free list of the present tariff.

Bismuth imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1868	....	$30,149	1877	....	$12,279
1869	....	29,047	1878	....	45,838
1870	....	30,695	1879	....	47,523
1871	....	47,047	1880	....	82,711
1872	....	40,554	1881	....	83,209
1873	....	17,025	1882	64,837	111,087
1874	....	14,179	1883	54,702	89,683
1875	....	8,723	1884	61,208	93,548
1876	....	10,458			

ARSENIC.

Although occurrences of arsenic ores are frequent throughout the United States, especially in the far West, there is no commercial production. In the eastern and central portions of the country the deposits are generally small and scattered. In the gold and silver ores of the Rocky Mountain region and the Pacific coast arsenic is very common, but is regarded only as a hinderance in metallurgical operations. Auriferous mispickel is worked on a considerable scale for its gold contents; and sulpharsenide silver ores are frequent, sometimes being treated by chloridizing roasting followed by amalgamation, and sometimes smelted with the silver-lead ores with which they occur. Both in roasting and smelting large quantities of arsenic pass off in the fumes and are lost. The cheapness of the product and the distance from market have thus far prevented it from being saved in commercial quantities, though in time a small production may be looked from the gold and silver reduction works.

Metallic arsenic is produced in only small quantities and has a limited application in the arts, usually as the hardening element in lead alloys. The yellow sulphide, or orpiment (As_2S_3), and the red sulphide, or realgar (AsS), are more largely used, mainly as pigments and in fireworks. White arsenic, the "arsenic" of commerce, is arsenious oxide (As_2O_3), and is the common form. From it the other arsenic compounds, so largely used in the arts, are readily made. It is produced as a by-product in metallurgical operations, very seldom being a main product.

The imports of white arsenic are very large, amounting to 1,800 tons in the last fiscal year, mainly from England. The nearest source of supply is the Del Oro mine, Ontario, Canada, where it is obtained by roasting a gold-bearing mispickel ore preliminary to the extraction of the gold. This mine is worked by an American company. There was no production of arsenic in 1883 at the Del Oro mine, but in 1884 about 200 short tons were made. In the crude state it carried about 97 per cent. of pure arsenious oxide, and when refined some of it is said to have reached 99.65 per cent., the usual grade of English refined being about 95 per cent. The Del Oro arsenic is only just coming on the market; but the full capacity of the works, if running regularly, is stated by Mr. R. P. Rothwell, the manager, at about 1,000 tons per year, or about one-eighth of the entire make of the world.

At the close of 1884 the price of English refined white arsenic was 2¾ cents per pound, wholesale.

Recent imports have been as follows:

Arsenic imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	....	$17,700	1876	447,019	$13,784
1868	1,442,142	19,191	1877	2,588,948	71,738
1869	1,442,576	29,450	1878	2,471,861	56,662
1870	566,500	12,643	1879	2,445,852	52,715
1871	1,329,693	29,822	1880	2,717,777	62,207
1872	1,109,811	30,337	1881	2,225,425	54,056
1873	612,116	16,373	1882	3,396,334	89,111
1874	1,636,335	39,985	1883	5,207,553	121,891
1875	2,327,742	49,430	1884	3,693,325	86,316

ALUMINUM.

BY R. L. PACKARD.

Increased utilization.—Within the last two years the useful properties of aluminum have become better known to manufacturers and the public generally through publications in trade and other journals, and this information has excited considerable interest in the present condition and the prospects of the manufacture of that metal and in the various applications of which it is capable. It is reported that a large collection of articles made of aluminum was shipped from England to Calcutta for exhibition in the latter part of 1883. This exhibit was said to consist of wire, pens, pencil cases, railway-carriage fittings, locks and bolts, harness furniture in great variety, chandeliers, cutlery, and ships' fittings, and sufficiently illustrates the various uses to which the metal can be put.

Aluminum is coming into use in the manufacture of alloys, such as aluminum bronze. In the United States it is being more extensively employed in making the lighter parts of such instruments as galvanometers and other physical instruments used in scientific experiments, for delicate weights, suture wire, and in engineering, astronomical, and optical instruments. It is sold as leaf in books, like gold leaf, for decorators, at from 40 to 50 cents a book, and is being experimented with by manufacturers of jewelry. The amount made in France in 1882 was 2,349 kilograms. In Germany experiments are being made with it as a coating for iron, to be applied for ornamental purposes, and as an improvement upon tin plate. Its use is extending slowly but surely, its cost being at present the principal obstacle to its wider employment.

The price of American aluminum ranged from 75 cents to $1 per ounce troy in 1883, and from 50 cents to $1 per ounce in 1884, according to quantity. In the fiscal year 1884 the imports were 554 pounds avoirdupois, valued at $7,463.

Until recently the aluminum sold in the United States was entirely of foreign origin, but it is now produced in this country by a process patented by Col. William Frishmuth, of Philadelphia, who turned out 1,000 ounces of the metal in 1883 and 1,800 ounces in 1884.

It should be said here that the aluminum cap or apex of the Washington Monument was cast by Colonel Frishmuth. It is of pyramidal form, is about 10 inches high, its base is 6 inches on a side, and it weighs 100 ounces. The metal of the apex has the following composition:

	Per cent.
Aluminum	97.75
Iron	1.70
Silicon	.55
	100.00

Metallurgy.—The Frishmuth process for extracting aluminum, as described in the patents, differs from the French or Deville method in substance, as follows: The Deville process consisted essentially in converting alumina into chloride of aluminum by passing chlorine through a heated mixture of alumina, carbon, and common salt in a retort, whereby the chloride was distilled off and was recovered, and then acting on the chloride by sodium on the hearth of a reverberatory furnace. Frishmuth converts the alumina (in the form of corundum, bauxite, etc.) into fluoride by fusing the mineral with fluoride of sodium after a previous heating with fluorspar. The fluoride of aluminum and sodium so obtained is then powdered, mixed with carbon and with the chlorides of sodium and potassium, and placed in a retort with a false bottom. Connected with this retort by a suitable pipe is another, into which he introduces carbonate of soda, charcoal, and lime. On heating the retorts vapor of sodium passes from the retort containing the soda mixture, which must be at a white heat, through the mixture containing the fluoride of aluminum and sodium, and separates the aluminum. The operation is varied by converting the fluoride of aluminum into chloride and treating that with sodium vapor in the same way as the fluoride.

A statement has recently appeared in the papers that a method has been proposed for obtaining aluminum from kaolin by mixing together "zinc ore," kaolin, carbon, pearl ash, and common salt, and distilling off zinc and aluminum to be afterwards separated. The description of the process given in the papers is, however, too vague to be clearly understood, and there is no statement of the amount of aluminum produced in this way.

Soldering aluminum.—A practical obstacle in working aluminum has been the difficulty of soldering it. A French alloy for this purpose is said to be composed of 45 parts of tin and 10 of aluminum, for pieces which are to be worked after soldering, while for other purposes the proportion of aluminum may be less. The following alloys have also been recommended: Silver, 10 parts; copper, 10; aluminum, 20; tin, 60, and zinc, 30 parts. This alloy is said to be good for chains, etc., and can be used in blowpipe operations. For a solder to be used with the common soldering iron, 95 to 98 parts of tin and 5 to 2 parts of bismuth. The "fuse" to be used is paraffine, stearine, vaseline, or balsam copaiba. The articles must be well cleaned, and the parts to be soldered must be heated enough to make the solder adhere. These formulas may be interesting to workers in aluminum, and may at least suggest lines of further experiment.

Aluminum imported and entered for consumption in the United States, 1870 *to* 1884 *inclusive.*

Fiscal years ending June 30–	Quantity.	Value.	Fiscal years ending June 30–	Quantity.	Value.
	Pounds.			*Pounds.*	
1870	....	$98	1878	251	$2,978
1871	....	341	1879	284.44	3,423
1873	2	2	1880	340.75	4,042
1874	683	2,125	1881	517.10	6,071
1875	434	1,355	1882	566.50	6,459
1876	139	1,412	1883	426.25	5,079
1877	131	1,551	1884	590	8,416

ZIRCONIUM.

BY DAVID T. DAY.

Occurrence.—Zirconium is always found as the silicate, zircon, or rarely in the modified form called hyacinth. It occurs in crystalline rocks, and especially in granular limestone. Madison county, North Carolina, is the most noted zircon locality in this country; the mineral occurs there in well defined crystals, which contain small amounts of iron. Only a few pounds have been obtained from the farm of Gen. T. L. Clingman, at Asheville, in this county, for purposes other than cabinet specimens. The finest crystals have been obtained from Canada. Moriah, in Essex county, New York, has also produced some good crystals. Zircon is also met with occasionally in Maine, Vermont, Massachusetts, Connecticut, and Pennsylvania. It has been found quite freely at Franklin, New Jersey.

Experiments with a view to utilization.—It has frequently been proposed to use pencils of the oxide of zirconium for producing an incandescent light. This oxide is very infusible, and when heated glows with a very white light. The obstacles to its use are, however, serious. It is extremely difficult to decompose the silicate and obtain the oxide from it. To purify this oxide is another difficult matter. Comparative tests between zirconia and lime for incandescent lights have shown that zirconia has the one advantage of not taking up moisture as lime does. In 1882 an effort was made to produce an incandescent electric light by inclosing carbon points in a cylinder of zirconia without access of air. It was found by inquiry that only one-half ounce of zirconia could be bought in the United States; enough was prepared in Baltimore and at Columbia College, New York, to use in the experiments, which have not yet, however, been completely successful. It is more than possible that such a use as this may yet bring zircon to market.

STRUCTURAL MATERIALS.

BUILDING STONE.

Present status.—The value of the building stone quarried in the United States during the past three years is estimated as follows:

1882	$21,000,000
1883	20,000,000
1884	19,000,000

A complete canvass of the quarries is evidently impracticable with the means at command—the census investigation of building stones having cost many times the whole expense of the present work—and no effort has been made in this direction. The foregoing estimates are based upon these considerations: The output during the census year 1879–1880 was placed at $18,356,055, the returns, however, not including quarries yielding less than $1,000 worth during that year. Assuming the census figure as nearly correct, with the qualification just stated, a fair estimate for 1882 could not fall below $21,000,000, and this was probably a very close approximation to the truth. A comparison with the census results is much less to be relied on for subsequent years, but the valuation for 1883 is placed at $20,000,000, notwithstanding the known increase in building activity during that year as compared with 1882, because of the marked preference for brick construction, which more than offset that general activity. For 1884 the estimate is still more uncertain, but the general industrial decline, and the prevailing fashion in choice of building material, certainly reduced the value of the stone quarried, and the falling off may be roughly indicated by the estimate, $19,000,000. However faulty these estimates may be, they at least express the opinion of the builders who have been consulted.

Brick in a general way, pressed brick, and brick and terra cotta work combined, especially on the Atlantic seaboard, have superseded stone to about the extent indicated above, and the change may be attributed in part to economical measures. Many architects and builders still give decided preference to stone where it can be used within the limits of proposed expenditure, the sandstones for dwellings, especially on fronts of rows of city houses, and the granite for large and imposing edifices. Marble as a building stone appears to have entirely gone out of fashion in the neighborhood of New York City, and large quarries in the adjacent county of Westchester are for the present practically abandoned. Similar conditions prevail in other portions of the country, though the

Vermont marbles, dressing to a harder, smoother, and durable surface, retain a good market for trimmings, monumental work, etc. The bluestone of Ulster county, New York, has extensive use for building purposes in the way of steps, platforms, sills, and lintels, in addition to a liberal consumption for flagging, and is distributed over all parts of the adjoining States.

The building stones of the eastern States have been minutely described in Volume X. of the census reports. On page 453 *et seq.* of "Mineral Resources of the United States, 1882," will be found a notice of the stones of the Rocky Mountain region, to which nothing need now be added. Mr. Yale furnishes the following notes, in continuation of the description given in the former report, on the Pacific coast building stones:

Building stone on the Pacific coast.—The rocks most employed for building and similar purposes abound almost everywhere in the Pacific division, many heavy ranges of mountains being composed mainly of the more common kinds, such as granite, diorite, sandstone, limestone, slate, "porphyry," etc. The Sierra Nevada, the longest and loftiest chain west of the Rockies, consists almost wholly of granite. Very little stone is, however, obtained from the main range, most of the granite quarries worked in California being situated on the lower foothills of the Sierra, some of them at an elevation of only a few hundred feet above tidewater. While the principal granite quarries are located in Placer county, California, on the line of the Central Pacific railroad, some granite is quarried in other parts of the State, this latter stone being mostly for local uses. The quarrying of granite was commenced in California as early as 1853, large quantities from that time on being required for both public and private buildings. Prior to that date several cargoes of granite were imported from China, the blocks being already dressed ready for use. A number of stores were built in San Francisco from this material, all of which are still standing and in a good state of preservation. A few buildings were also at the same time, or a little later, constructed in that city, of marble brought from Vermont, none of these, so far as the stone is concerned, being any the worse from the lapse of time. Besides being much used in the construction of stores, warehouses, etc., granite in connection with cobbles and basalt blocks has been largely employed for street paving in San Francisco. A great deal of this stone has also gone into the fortifications. The light-house now in course of construction on Saint George's reef, on the northern coast of California, consists of granite obtained from a deposit recently discovered on Mad river in that neighborhood. The stone exists here under conditions that render it easily available, the whole face of the mountain being covered with loose blocks of granite, some of which weigh hundreds of tons. A great deal of California granite is also being used in the construction of the new dry dock at Mare Island navy yard, San Francisco bay. In the Pacific division, outside of California, not much has been made of this stone, cheaper building material having usually been made to answer in its stead; this having been to a great extent the case also with the other useful stones, such as diorite, basalt, limestone, marble, slate, etc. A species of lava rock, soft and easily cut when first quarried, but which hardens when exposed to the air, has been employed for building in these western regions, especially where lumber is scarce. So also has sandstone for like purposes come into large use there, the branch mint in San Francisco, the great Mormon temple and the immense building known as the Tabernacle in Salt Lake City, Utah, being constructed of this material. The sandstones of the Pacific States and Territories are of all varieties and colors, light drab, yellow, red, brown, etc. In a low range in central Nevada a sandstone is found which answers well for the construction of metallurgical furnaces, some of it having been used for that purpose with excellent results.

During the past year many samples of building stone were submitted to the architects of a dwelling to be built in San Francisco for a wealthy citizen. The investigation proved that choice building material was abundant, but that the cost of freight, etc., and the lack of development of the quarries were against its use. It was the original intention to build with stone quarried in California. Samples from all parts of the State were submitted and over fifty of them were tested. A number were found to meet all requirements, among them being varieties of granite, marble, sandstone and brownstone, and "blacklog." But it was found that the cost of getting either of these stones to San Francisco in the desired shape would be so high that the same material could be brought from the eastern States at a much lower cost. For instance, it would cost as much to break out California marble and send it by rail as to bring marble by sea from Italy, while the latter stone could be worked more readily. The fine Penrhyn granite was not selected because of similar reasons and as a matter of personal taste. Of brownstone there were two excellent samples, one from an island off the coast of Lower California, and the other from Solano county. In both cases the quarries required to be opened. A company was formed to quarry the "blacklog" stone, which is of a bluish gray color and is found in Oregon just north of the California line. But in this case the building of 10 miles of railroad and a breakwater would be necessary. For these reasons it was finally decided to obtain stone from the eastern States. The case was of course an exceptional one.

Basalt, "trachyte," and other volcanic rocks are common in the far West, the former often showing the columnar structure in great perfection. Good building and roofing slates are also abundant, that from some localities being an excellent material. From the beds in San Bernardino county large slabs, thin, smooth, and straight can be readily split.

Besides the numerous and extensive beds of marble in California and the other Pacific States and Territories, this stone seems to occur in great abundance and of good quality in Alaska. As early as 1867 Prof. George Davidson reported finding on Baranoff island, 10 miles north of Sitka, a large deposit of marble, which he described as being a pure white, finely crystallized stone, free from marks and stains, rendering it very desirable. Believing this to be a valuable deposit a company has been formed in San Francisco to work it on an extensive scale.

Imports and exports.—The following tables show the extent of the foreign commerce of the United States in marble and other stone:

Marble imported and entered for consumption in the United States, 1867 *to* 1883 *inclusive.*

Fiscal years ending June 30—	Sawed, dressed, etc., not over 2 inches in thickness.	Sawed, dressed, etc., over 2 and not over 3 inches in thickness.	Sawed, dressed, etc., over 3 and not over 4 inches in thickness.	Sawed, dressed, etc., over 4 and not over 5 inches in thickness.	Sawed, dressed, etc., over 5 and not over 6 inches in thickness.	Veined and all other in blocks, etc.	White, statuary, Brocatella, etc.	Not otherwise specified.	Total.
1867	....	....	....	....	....	$192, 514	$2, 540	$51, 978	$247, 032
1868	....	....	....	....	....	309, 750	4, 403	85, 783	399, 936
1869	....	....	....	....	....	359, 881	3, 898	101, 309	465, 088
1870	....	....	....	....	....	332, 839	3, 713	142, 785	479, 337
1871	$5, 973	$168	$77	$44	$28	400, 158	1, 134	118, 016	525, 598
1872	3, 499	1, 081	452	....	318	475, 718	4, 017	54, 539	539, 624
1873	3, 124	21	....	....	....	396, 671	4, 148	69, 991	473, 955
1874	1, 837	....	....	....	....	474, 680	2, 863	51, 699	531, 079
1875	1, 456	427	96	....	....	527, 628	1, 623	72, 389	603, 619
1876	595	126	204	87	....	529, 126	1, 151	60, 596	591, 885
1877	2, 124	....	....	....	....	349, 590	1, 404	77, 293	430, 411
1878	198	11	8	....	....	376, 936	592	43, 915	421. 660
1879	184	....	....	....	....	329, 155	427	54, 857	384, 623
1880	....	....	....	....	....	531, 908	7, 239	62, 715	601, 862
1881	339	....	....	....	....	470, 047	1, 468	82, 046	553, 900
1882	655	....	....	....	....	486, 331	3, 582	84, 577	575, 145
1873	619	....	....	....	....	533, 096	2, 011	71, 905	607, 631

In 1884 the classification was as follows:

	Value.
Marble:	
In block, rough or squared, of all kinds	$511, 287
Veined marble, sawed, dressed, or otherwise, including marble slabs and marble paving-tiles	12, 941
All manufactures of, not specially enumerated	67, 829
Total	592, 057

Building stone (exclusive of marble), paving stone, and stone ballast imported and entered for consumption in the United States, 1867 to 1884 inclusive.

Fiscal years ending June 30—	Building stone, dressed.	Building stone, rough.		Sandstone.	Slate chimney pieces, mantles, etc.	Roofing slate.	Limestone.	Paving stones.	Ballast.	Total value.
		Quantity.	Value.							
		Long tons.								
1867	....	....	....	....	$37, 510	$85, 204	....	....	....	(?)
1868	$59, 081	....	....	....	16, 045	118, 776	....	$5, 718	....	(?)
1869	61, 408	....	$8, 237	$4, 171	19, 602	85, 364	....	467	$3, 987	(?)
1870	150, 619	....	....	3, 201	19, 879	107, 521	....	2, 034	10, 518	(?)
1871	145, 759	1, 455	16, 982	3, 660	21, 381	117, 484	....	....	34, 703	(?)
1872	162, 614	10, 723	39, 515	7, 680	25, 925	107, 192	$2, 459	5, 529	11, 303	$362, 217
1873	218, 236	20, 226	73, 889	6, 160	26, 643	91, 503	1, 486	3, 788	17, 143	438, 848
1874	238, 680	19, 658	81, 645	8, 534	27, 519	80, 519	1, 639	7, 246	21, 882	467, 664
1875	275, 633	15, 748	67, 357	10, 986	42, 022	16, 342	2, 023	2, 017	9, 025	425, 405
1876	316, 404	8, 199	34, 124	7, 174	44, 266	2, 051	1, 938	1, 005	9, 350	416, 312
1877	201, 034	7, 584	25, 571	5, 492	34, 479	4	1, 705	485	6, 272	275, 042
1878	153, 693	10, 197	37, 878	7, 136	39, 935	275	2, 614	1, 950	6, 989	250, 470
1879	125, 493	6, 845	24, 531	13, 956	46, 260	620	1, 456	2, 943	2, 365	217, 624
1880	75, 501	11, 035	43, 997	10, 220	51, 165	72	2, 560	2, 383	7, 572	193, 470
1881	76, 741	15, 867	65, 950	15, 115	46, 862	2	1, 990	3, 799	5, 401	215, 860
1882	104, 296	16, 778	75, 369	....	45, 774	154	2, 710	16, 599	8, 792	253, 694
1883	127, 476	14, 324	64, 767	....	44, 375	2, 813	1, 841	2, 629	5, 745	249, 646
1884	122, 463	12, 198	50, 860	....	34, 640	16, 099	143	2, 576	2, 551	229, 332

Marble and stone of domestic production exported from the United States.

Fiscal years ending September 30, until 1842, and June 30 since.	Rough.	Manufactured.	Total.	Fiscal years ending June 30—	Rough.	Manufactured.	Total.
1826	....	$13, 303	$13, 303	1856	....	$162, 376	$162, 376
1827	....	3, 505	3, 505	1857	....	111, 403	111, 403
1828	....	3, 122	3, 122	1858	....	138, 590	138, 590
1829	....	2, 647	2, 647	1859	....	112, 214	112, 214
1830	....	4, 655	4, 655	1860	....	176, 239	176, 239
1831	....	3, 588	3, 588	1861	....	185, 267	185, 267
1832	....	3, 455	3, 455	1862	....	195, 442	165, 442
1833	....	5, 087	5, 087	1863	....	138, 428	138, 428
1834	....	7, 359	7, 359	1864	$57, 715	144, 647	202, 362
1835	....	8, 687	8, 687	1865	74, 261	183, 782	258, 043
1836	....	4, 414	4, 414	1866	89, 703	112, 830	202, 533
1837	....	5, 374	5, 374	1867	53, 983	138, 558	192, 541
1838	....	5, 199	5, 199	1868	60, 399	105, 046	165, 445
1839	....	7, 661	7, 661	1869	62, 266	87, 135	149, 401
1840	....	35, 794	35, 794	1870	42, 227	138, 046	180, 273
1841	....	33, 546	33, 546	1871	135, 672	137, 613	273, 285
1842	....	18, 921	18, 921	1872	156, 976	165, 311	322 287
1843 (nine months)	....	8, 545	8, 545	1873	96, 735	189, 795	286 530
1844	....	19, 135	19, 135	1874	126, 669	168, 977	295 646
1845	....	17, 626	17, 626	1875	125, 968	254, 356	380, 324
1846	....	14, 234	14, 234	1876	95, 480	236, 255	331, 735
1847	....	11, 220	11, 220	1877	131, 716	917, 937	1, 049, 653
1848	....	22, 466	22, 466	1878	142, 661	597, 356	740, 017
1849	....	20, 282	20, 282	1879	143, 457	430, 848	574, 305
1850	....	34, 510	34, 510	1880	199, 051	453, 912	652, 963
1851	....	41, 449	41, 449	1881	220, 362	409, 433	629, 795
1852	....	57, 240	57, 240	1882	180, 774	433, 656	614, 430
1853	....	47, 628	47, 628	1883	152, 182	389, 371	541, 553
1854	....	88, 327	88, 327	1884	188, 245	415, 015	603, 260
1855	....	168, 546	168, 546				

Marble and stone, and manufactures of marble and stone, of foreign production exported from the United States, 1872 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1872	$1,929	1879	$6,364
1873	4,571	1880	6,816
1874	1,928	1881	709
1875	3,428	1882	4,848
1876	13,371	1883	490
1877	8,475	1884	8,420
1878	3,448		

Summarizing the foregoing statistics, the movement during the fiscal years 1882, 1883, and 1884, may be stated thus:

Balance of trade in marble and stone.

Fiscal years ending June 30—	Imports.	Exports.			Excess of imports over exports.
		Of domestic production.	Re-exports of foreign production.	Total exports.	
1882	$828,839	$614,430	$4,844	$619,278	$209,561
1883	1,475,658	541,553	490	542,043	933,615
1884	821,389	603,260	8,420	611,680	209,709

In addition to the domestic exports tabulated, there are occasional insignificant exports of roofing slate, amounting in 1871 to $1,256, and in 1881 to $1,018.

BUILDING SAND.

In the Atlantic States a large proportion of the sand used in building is obtained in the course of excavating for foundations, and the cost in such case may range as low as 50 cents per long ton. When dug especially for the purpose, the average cost, exclusive of haulage, may be placed at about 75 cents per ton. This is of course higher in the West, where labor is dearer. Besides its use in mixing mortars and cements, in most large cities there is a considerable consumption of sand for corporation work on streets, where it is used sometimes to the extent of 1 cubic yard (about 1 short ton) of sand to 6 superficial yards of paving. In mixing mortar the usual proportion is said to be 9 or 10 per cent. lime, and the balance sand; with cement from natural rock from 25 to 40 per cent. cement, and with foreign cements 15 to 20 per cent. cement and the remainder sand. The difference in the quantity of cement used is dependent upon the strength desired, and mixers seldom agree as to exactly what proportions should be observed. In practice by no means the attention is given to the sharpness of the sand that is recommended in the books.

Imports and exports of sand and gravel.

Fiscal years ending June 30—	Imports.	Exports.
1864		$5,109
1865		9,438
1869	$12	629
1870	65	3,983
1871	2,191	7,069
1872	4,102	5,893
1873	981	11,522
1874	813	13,802
1875	100	8,509
1876		$9,013
1877		10,803
1878	$31	17,017
1879	212	8,482
1880		11,266
1881		15,676
1882		22,080
1883	274	25,708
1884	16,360	19,399

LIME.

It seems unadvisable to attempt a detailed description or even list of the numerous sources of lime in the United States. There is hardly a county in any State or Territory in which there are not one or more places where lime is burned, though the importance of the industry varies greatly in different portions of the country. A number of detailed reports on scattered localities have been received; but want of space and the irregular character of the information furnished do not warrant their publication.

The following estimates are based upon the known output of many of the more important districts and the opinions of dealers at trade centers:

Estimated production of lime in the United States in 1882, 1883, *and* 1884.

Years.	Barrels of 200 pounds.	Average value at kiln.	Total value.
1882	31,000,000	$0.70	$21,700,000
1883	32,000,000	60	19,200,000
1884	37,000,000	50	18,500,000

The considerable increase in the output of 1884 is due in a great measure to the development of new sources of supply, especially along the line of the Missouri and Mississippi rivers, and in Texas. The shrinkage in cost is simply the natural sequence of competition between an increased number of manufacturers anxious to obtain a market, somewhat modified rates of production, and a condition of business affording consumers better opportunities to dictate terms than for many years preceding. The information received also leads to the inference that the addition to the supply has been largely of medium or poorer quality, and this important factor has been duly considered in estimating average values.

The production of 37,000,000 barrels of lime presupposes the burning of about 6,600,000 short tons of limestone, without allowances for moisture.

Imports and exports.—The imports of lime are very small, as would be expected. The table of exports, derived from the custom-house records, does not segregate lime from cement; and from the ratio of quantity to value it will be seen that the greater portion of the exports classified under this head must consist of cement:

Lime imported and entered for consumption in the United States.

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Barrels.			*Barrels.*	
1869	....	$10, 800	1877	....	$12, 823
1870	....	9, 063	1878	....	14, 344
1871	....	11, 315	1879	....	13, 196
1872	....	11, 014	1880	....	15, 852
1873	....	8, 260	1881	....	24, 968
1874	....	10, 964	1882	73, 093	36, 879
1875	....	7, 328	1883	76, 889	41, 224
1876	....	7, 367	1884	52, 467	26, 375

Lime and cement of domestic production exported from the United States, 1864 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Barrels.			*Barrels.*	
1864	....	$86, 386	1877	78, 341	$97, 923
1865	....	94, 606	1878	82, 507	98, 334
1870	31, 175	61, 490	1879	60, 657	74, 097
1871	21, 575	51, 585	1880	41, 989	52, 584
1872	39, 686	69, 218	1881	57, 555	83, 598
1873	27, 873	52, 848	1882	67, 030	100, 169
1874	41, 349	69, 080	1883	74, 687	120, 156
1875	64, 087	98, 630	1884	65, 768	108, 437
1876	53, 827	77, 568			

Limestone flux.—Limestone is used in large quantities as a flux in smelting iron and lead ores. No statistics of the consumption in lead smelting have been obtained, but Mr. Swank has estimated the amount and value of the limestone used in iron smelting during the last three years as follows:

Limestone used as flux in iron smelting in the United States in 1882, 1883, *and* 1884.

Years.	Quantity.	Average cost at quarry.	Total value.
	Long tons.	*Per ton.*	
1882	3, 850, 000	$0. 60	$2, 310, 000
1883	3, 814, 273	. 50	1, 907, 136
1884	3, 401, 930	. 50	1, 700, 965

The following table, prepared by Mr. John M. Hartman and published in the *Bulletin of the American Iron and Steel Association*, gives the value of limestone containing various amounts of silica, lime, and magnesia. The basis of the calculation is magnesian limestone at 56 cents per ton and fuel at $3.50 per ton, both at the furnace. The siliceous character of all American iron ores requires the use of twice the amount of limestone to each ton of fuel used in our furnaces as is required in foreign furnaces. The carbonic acid from this extra amount of limestone burns away the fuel at the top (by Bell's E reaction), and is one cause of the excess of fuel used in this country. Limestone is a great heat absorbent, and an excess of it performs two things in the furnace: First, it purifies the iron from sulphur, giving a larger, darker grain; and, second, its cooling action prevents the reduction of silica to silicon, and therefore prevents the light color sometimes found in foundry pig iron. Magnesian limestone will remove phosphorus to a certain extent.

Relative value of limestone as flux.

Limestone.			Magnesian limestone.											
Silica.	Lime.	Value.	Silica.	Lime.	Magnesia.	Value.	Silica.	Lime.	Magnesia.	Value.	Silica.	Lime.	Magnesia.	Value.
P. ct.	*P. ct.*	*Cents.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cents.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cents.*	*P. ct.*	*P. ct.*	*P. ct.*	*Cents.*
0	55	57	0	37	16	64	0	41	12	61	0	45	8	59
1	54	54	1	37	16	61	1	41	12	58	1	45	8	56
2	53	51	2	36	16	58	2	40	12	56	2	44	8	53
3	52	48	3	36	16	56	3	40	12	53	3	44	8	51
4	51	45	4	35	16	53	4	39	12	50	4	43	8	48
5	50	42	5	35	16	50	5	39	11	47	5	43	7	45
6	50	39	6	34	15	48	6	38	11	45	6	42	7	42
7	49	36	7	34	15	45	7	38	11	43	7	42	7	40
8	49	33	8	33	15	42	8	37	11	40	8	41	7	37
9	48	30	9	33	15	39	9	37	11	37	9	41	7	34
10	48	27	10	32	15	36	10	36	11	34	10	40	7	31
11	47	25	11	32	15	34	11	36	10	32	11	40	6	29
12	47	23	12	31	14	31	12	35	10	29	12	39	6	26
13	46	20	13	31	14	28	13	35	10	26	13	39	6	23
14	46	17	14	30	14	25	14	34	10	23	14	38	6	20
15	45	14	15	30	14	22	15	34	10	20	15	38	6	17

Lime in glass-making.—The use of lime in the manufacture of glass is discussed by Mr. Weeks elsewhere in this volume under the head of "glass materials." Mr. Weeks estimates the annual consumption of limestone in the glass works of the United States at about 3,500 tons, and of lime, 900,000 to 1,000,000 bushels.

CEMENT.

Production.—A careful estimate of the production of artificial (American Portland) cement, made by Mr. Henry S. Sproull, of the New York *Real Estate Record and Guide*, who has also furnished much of the information given under this head, gives the following results:

Production of American Portland cement in 1882, 1883, *and* 1884.

Years.	Barrels of 400 pounds.	Average price per barrel.	Total value.
1882	85, 000	$2 25	$191, 250
1883	90, 000	2 15	193, 500
1884	100, 000	2 10	210, 000

For cement manufactured from natural rock the estimate is not so accurate, but will not be very wide of the mark, and where doubts have arisen between the adoption of an extreme or a more conservative indication, as developed through different sources of information, the minimum figure was selected. The results are as follows:

Production of cement made from natural rock in the United States in 1882, 1883, *and* 1884.

Years.	Barrels of 300 pounds.	Average price per barrel.	Total value.
1882	3, 165, 000	$1. 10	$3, 481, 500
1883	4, 100, 000	1. 00	4, 100, 000
1884	3, 900, 000	90	3, 510, 000

The total production of all kinds of cement during the past three years has been as follows:

Total production of all kinds of cement in the United States in 1882, 1883, *and* 1884.

Years.	Barrels.	Value.
1882	3, 250, 000	$3, 672, 750
1883	4, 190, 000	4, 293, 500
1884	4, 000, 000	3, 720, 000

The product of Ulster county, New York, in 1883 was very close to 1,800,000 barrels, and that of the whole State was 2,200,000 barrels. The product of Ulster county in 1884 ran down to about 1,650,000 barrels, and that of the entire State to 2,000,000 barrels.

Manufacturing centers.—The leading points of manufacture for the United States are as follows:

Localities.	Factories.
Artificial cement:	
Egypt, Pennsylvania	1
Coplay (near Allentown), Pennsylvania	1
Natural rock cement:	
Rosendale, New York	15
Louisville, Kentucky	10
Buffalo, New York	3
Akron, New York	2
Utica, Illinois	2
Milwaukee, Wisconsin	1
Mankato, Minnesota	1

Besides these, there are other works at Sandusky, Ohio; Kensington, Connecticut; Cumberland and Round Top, Maryland; Shepherdstown, West Virginia; on the James river, Virginia; Rockland, Maine; South Bend, Indiana; Fort Dodge, Iowa; Denver, Colorado; and Benicia, California.

Kinds made.—The rock cements made at the various points enumerated are simply a hydraulic lime, grading quite uniformly as to quality and differing principally in color. The difference in price between artificial and rock cements is indicated in the average rate per barrel, as given in the estimate of the value of the production. There is little difference, so far as known, in the production cost of the natural cements. Domestic cements are used for all ordinary building and foundation work, including submarine operations, and also find favor in the manufacture of paving blocks and surfaces as a mixture with the foreign cement. They were at one time used to a moderate extent in the production of drain and sewer pipe, but with indifferent success.

Imports.—The steady growth of the import trade in cement is a matter of no little significance, and is best indicated by the following statement of receipts at the port of New York during the years named:

Imports of cement at New York, in packages of 400 *pounds.*

Years.	From Great Britain.	From European continent.	Total.
1877	47, 632	10, 818	58, 450
1878	51, 477	19, 040	70, 517
1879	80, 834	25, 212	106, 046
1880	120, 833	45, 080	165, 913
1881	149, 486	73, 186	222, 672
1882	171, 202	190, 924	362, 126
1883	158, 602	143, 363	301, 965
1884	155, 477	201, 085	356, 562

Imports have also been made at Boston, Philadelphia, New Orleans, and some of the South Atlantic ports, and also at San Francisco a small amount is re-exported. The total imports (classed as "Roman" cement at the custom-houses) into the United States since 1868 have been:

Roman cement imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Barrels.			*Barrels.*	
1868		$10,168	1877		$201,074
1869		9,855	1878		184,086
1870		18,057	1879		212,719
1871		52,103	1880		373,264
1872		172,339	1881		441,512
1873		209,097	1882	370,406	683,684
1874		286,429	1883	456,418	802,294
1875		261,741	1884	*a*585,768	825,095
1876		247,200			

a Classed simply as cement; kind not specified.

With only one exception (a continental brand) the imported cements are artificial. The average cost laid down on pier at New York City, per barrel of 400 pounds, compares as follows:

Years.	Per barrel.
1882	$2.60
1883	2.70
1884	2.50

Of the imported cement it would be a liberal estimate to allow 5 per cent. for the fancy grades known as Keene's, etc., and as a rule brought out only on specific orders. These are white cements of peculiarly fine quality, and used in the production of terra cotta trimmings, imitation stone work (marble in particular), extra hard finish for walls, etc. The balance of the importation is composed of "Portland," a building cement well adapted to all general work, but especially a favorite for submarine operations. It is also used largely in the preparation of patent pavement blocks and similar products of artificial stone. It has within two years found much favor in this country for cellar linings and the construction of silo pits for the preservation of fodder in the agricultural districts; and has universal consumption, urban, suburban, and country, in the laying of foundations for all kinds of edifices. The English-made cements come principally through the port of London, and are mainly produced in the immediate vicinity of that city. They are made from the deposits of chalk and alluvial clays on the banks of the Thames and Medway, and are double silicates of lime and alumina. The continental product comes from Norway, Sweden, Germany, Belgium, and France. When kept well up to the standard upon which its reputation was established, foreign cement ranks superior to the domestic article both in setting and lasting conditions, but competition and hasty preparation have led to the importation of a great deal of stock much below the plane of merit possessed by even the poorest of the home product, and it remains on hand a worthless accumulation. In price the foreign article will average, delivered on pier, from $1.25 to $1.50 per barrel more than domestic.

Rocky Mountain division.—In 1881 it was accidentally discovered that the lime burned from one of the limestone beds near Cañon City, Colorado, possessed hydraulic properties, and experiments were begun with a view to the manufacture of cement. These experiments were continued, with but slight success on a large scale. In 1882 works were built at Denver, and every effort was made to secure the most favorable results. During that year about 100 barrels of excellent cement were made, and freely tested in various ways. While the cement stood every test satisfactorily, only a small portion of the rock burned acted well, over 90 per cent. being useless for hydraulic purposes. These experiments were continued until finally complete success was achieved. In the first week in May, 1883, the first entire kiln of cement was turned out, and the company was satisfied of its ability to produce a cement almost equal to the best Portland. The works and experiments cost about $30,000, and the capacity is now 20 barrels of 400 pounds net per day, or about 2,500 sacks of 100 pounds per month. The relative cost of the various brands of cement at Denver is as follows:

Portland, per barrel of 375 pounds net	$7.00 to $7.50
Louisville, per barrel of 265 pounds net	4.00
Denver, per barrel of 400 pounds net	6.00

During the latter part of 1883 the manufacture of cement by the Denver works was begun on a commercial scale, and an excellent product has since been made. This is now the cement most generally used in Colorado. It is used exclusively in the new post-office building now being erected at Denver, and for all the principal buildings in that city, as well as by the Denver and Rio Grande Railway. Its quality is said to be quite as good as that of the Portland cement. The works were closed at the end of 1884, on account of the small demand during the winter months. The limestone used by this company is taken from the "hogback" near Morrison. The calcareous marl used in the manufacture of the Denver cement is obtained from the "hogback" near Colorado City, in El Paso county. The production of cement by years has been:

Production of cement in Colorado.

Years.	Barrels.
1882	100
1883	1,200
1884	2,500
Total	3,800

Pacific coast.—At various places on the Pacific coast deposits of material for the manufacture of cement occur, but it is only in California that they have been utilized, and to no great extent in that State. A deposit was opened in Oregon some years ago, but it was not of an extensive character. The most notable occurrence in California is at Benicia, Solano county, on Carquinez straits. Large quantities of cement were made there for some years, and the product was quite popular. A company was formed to work the deposit, since which time very little has been done, though in January, 1885, operations were being recommenced. From another deposit of hydraulic limestone, recently found near Niles, in Alameda county, some excellent cement has been made. In the southern coast counties several deposits have been found, but they have not been utilized to any extent. The largest amount of cement ever made in California was in 1872, when the Benicia works turned out 25,500 barrels. There is an occurrence of cement at Santa Cruz, Santa Cruz county, which was worked for a time, and an extensive plant for burning the rock was put up. For the past few years, however, litigation and other difficulties have stopped the works, which are not now producing. None of the product was ever put upon the market.

Large quantities of cement are used in California, but the State depends almost entirely upon importations. The cement is used in the foundations of buildings and floors of basements, and with lime in making the various artificial stones. Only the best Portland cement is used for the latter purpose. In building the foundations and tubes for the beds of the cable railroads in San Francisco very large quantities of Portland cement have been used, the Market street road having required over 40,000 barrels to make the concrete. Both European and eastern cements are largely imported, the imports in 1883 and 1884 having been much greater than ever before; while during the past twenty years they have been as follows:

Imports of cement at San Francisco.

Years.	Barrels.	Years.	Barrels.
1864	13, 322	1875	73, 814
1865	26, 270	1876	66, 988
1866	34, 360	1877	45, 469
1867	31, 666	1878	57, 258
1868	31, 954	1879	15, 668
1869	54, 697	1880	62, 417
1870	42, 377	1881	65, 695
1871	32, 602	1882	99, 208
1872	54, 746	1883	151, 807
1873	61, 911	1884	152, 500
1874	79, 435		

As will be seen, this trade has increased very materially. The imports for 1884 were upward of 1,000 per cent. larger than for 1864. The imports for the past ten years have been 100 per cent. larger than for the first ten years of the foregoing table. The exports from San

Francisco are very small, amounting to only a few hundred barrels annually.

A light brecciated rock was found in 1884 near Berkeley, Contra Costa county, which was claimed to be pozzuolana, similar to that used by the Romans for cement. Mr. Samuel Kellett made experiments and announced it to be a hard-setting cement, but subsequently reversed his opinion, further experiments being less satisfactory. Mr. Hanks, the State mineralogist, in his experiments failed to produce a hard cement. Others claimed to have found a method for doing so, but kept the details a secret. A company has been formed to work the deposit, but so far none of the material has been placed upon the market. An analysis made by Mr. G. E. Moore is given below, and for comparison one of the true Roman pozzuolana:

	Berkeley cement rock.	Roman pozzuolana.
Silica	44.4	44.5
Alumina	15.6	15.0
Lime	8.6	8.8
Magnesia	4.1	4.7
Oxide of iron	11.6	12.0
Potash	1.5	1.4
Soda	3.9	4.1
Water	9.5	9.2
	99.2	99.7

There is a striking similarity in these analyses, if they are correctly reported; and it may be that the Berkeley rock is really a pozzuolana, in which case it would be a very valuable material.

The prices of cement in the San Francisco market on December 31, 1884, were as follows: Portland cement, $3.20 to $3.25 per barrel; Eastern Rosendale, $2.15 to $2.25, with an active market and a large stock of the former on hand; California building plaster, $3; Eastern casting plaster, $3 to $3.25; Eastern superfine, $4.50 to $5.

CLAYS.

By F. A. Wilber.

FIRECLAY AND POTTER'S CLAY.

The following section is intended as a supplement to the brief one on the above subjects published in the 1882 report. It is a difficult matter to describe in any adequate manner the location of the clay deposits of the United States, or the magnitude and importance of the industries connected with them. There is a great lack of authorities on the subject, as many of the States have not yet examined their resources in this direction, and consequently little has been published in regard to these deposits. The reports of State geologists, in those States which have conducted geological surveys, contain a large amount of information, but much of it is not available in giving a brief review of the subject, and statistical facts are very meager. In this paper the matter given is drawn from a variety of sources. Much is obtained from the various State reports on geology. Especial acknowledgments are here made of valuable aid received from the following sources:

"The Sixth Annual Report of the Bureau of Labor and Statistics of New Jersey," made by Mr. James Bishop. This report will be referred to as *A*.

"The clays of Ohio and the industries established upon them," by Edward Orton, jr., E. M., from Volume V., Geology of Ohio. Referred to as *B*.

"Report on the clay deposits of New Jersey," by Dr. George H. Cook, State geologist. This will be referred to as *C*.

"Statistics of the manufacture of drain tile in Illinois, compiled by the State Bureau of Labor Statistics," for 1883.

"Report of the Secretary of Internal Affairs of Pennsylvania," for 1883, Volume III.

"Reports of the Bureau of Statistics of Indiana," for the years 1880, 1881, 1882, and 1883.

Statistics are quoted from reports of the United States Bureau of Statistics, the *Brick, Tile, and Metal Review*, the *Record and Guide*, the San Francisco *Journal of Commerce*, the *Engineering and Mining Journal*, the *Age of Steel*, and various other journals. Information has also been received from Prof. Edward Orton, of Ohio; Prof. J. P. Lesley, Mr. Charles A. Ashburner, and Mr. C. B. Scott, of Pennsylvania; Prof. G. C. Broadhead, of Missouri; Mr. John Collett, State geologist of Indiana; and many other sources of private information have been consulted. The report for the Rocky Mountain division was made by Mr. F. F. Chisolm, and that for California by Mr. C. G. Yale.

The attempt has been made to give a brief review of (1) localities where clay deposits occur; (2) a list of articles manufactured from clay in the United States; (3) descriptions of the methods used in manufacturing the more important articles produced; (4) some notices of manufacturing localities, and such reliable statistics as could be obtained.

OCCURRENCES OF CLAY DEPOSITS.

District east of the Rocky mountains.—Few new fields of any great magnitude have been developed since the report issued for 1882, and the reader is referred to that for more particular mention of the occurrences of fire, common, and potter's clays. Large deposits of brick clay are reported in Maine, around its seacoast and stretching far inland. They are very noticeable along the Kennebec and Penobscot rivers. The clay is suitable for ordinary brick. Some promising deposits have been opened in Virginia, notably the one at Lipscomb, Augusta county, which is producing both fire and potter's clays. At Birmingham, Alabama, developments have been made. There are no doubt many other valuable deposits in the clay districts mentioned in the report of 1882, which will be developed as local demands cause search to be made for them. In *B* very particular mention is made of the clays of Ohio, and the same is true of the full report on those of New Jersey in *C*. These two volumes, together with the notices in the different State reports, constitute the literature on the subject of clays in the United States, and all reference to localities, etc., in these two States are quoted from them.

Rocky Mountain division.—No new localities have been reported during 1884, and reference is here made to the descriptions of the deposits in this division given on pages 472 to 475 of the report for 1882.

Pacific Coast division.—To quote Mr. Yale: "California abounds in clays adapted for making the coarser kinds of pottery as well as fire-brick, assayers' and chemists' wares, etc. It has at last been proved that the State possesses also a good porcelain clay, though the extent of the newly found deposits remains to be determined. The discovery of kaolin has frequently been reported in California, but not until recently have genuine deposits been found. In 1883 kaolin was discovered near the town of Calico, in San Bernardino county. While the quality of the material is excellent, and it occurs at several different points, the importance of the find is yet to be established, being dependent on the quantity of the clay here to be obtained. The useful clays, of varying degrees of excellence, are known to exist in considerable abundance at the following localities in California, their presence having also been observed at many other places: at the town of Lincoln, Placer county; near Antioch, Contra Costa county; in the vicinity of San Francisco, Oakland, San José, and Sacramento cities; at Michigan Bar on the Cosumnes river; near Mokelumne Hill, Calaveras county; Calico district, San Bernardino county; and at various places in Humboldt, Mendocino, Napa, Sonoma, Tehama, El Dorado, Inyo, Santa Barbara, and Los Angeles counties."

Analyses of California clays.

Localities.	Silica.	Alumina.	Sesquioxide of iron.	Carbonate of lime.	Magnesia.	Soda.	Combined water.	Hygroscopic water.	Loss.	Total.
Indurated clay, San Francisco	56.51	21.33	12.31	3.53 (Lime.)	Trace.	....	0.30	....	......	99.98
Clay near Lincoln, Placer county, called by the potters blue plastic clay	44.82	34.54	1.86	3.00	0.96	4.74	8.37	1.27	0.44	100.00
Clay near Lincoln, Placer county, called by the potters white non-plastic clay	41.80	38.78	2.12	2.64	1.02	3.46	6.00	1.62	2.56	100.00

ARTICLES MANUFACTURED FROM CLAY IN THE UNITED STATES.

I. BUILDING MATERIALS:
  1. Common building brick.
  2. Front building brick (pressed brick, molded, intaglio, or ornamental brick).
  3. Hollow brick.
  4. Glazed brick.
  5. Roofing tile.
  6. Flue linings.
  7 Door knobs and hardware porcelain.
  8. Terra-cotta lumber.
  9. Hollow tile, fireproofing, or castings.

II. REFRACTORY MATERIALS:
  1. Firebrick.
  2. Gas retorts.
  3. Retorts for zinc works and for other metallurgical purposes.
  4. Glass pots.
  5. Stove and furnace linings.
  6. Chemists' and assayers' utensils.

III. POTTERY:
  1. Stoneware.
  2. Earthenware (yellow ware, Rockingham ware).
  3. Granite or ironstone ware.
  4. Whiteware.
  5. Porcelain (as part of mixture).

IV. ORNAMENTAL WARE:
  1. Encaustic tile, for walls and floors.
  2. Ornamental pottery.
  3. Ornamental terra cotta.

V. MISCELLANEOUS:
  1. Sewer pipe.
  2. Drain pipe or drain tile.
  3. Flower pots.
  4. Garden border edging.
  5. Telegraph insulators.
  6. Well tubing.
  7. Receivers for acids.
  8. Water filters and coolers.
  9. Lamp stands.

Clay is also largely used in furnace work for luting, for weighting and sizing paper, and in making alum.

The above list illustrates the number and variety of articles made in the United States from the various grades of clay. The arrangement is, for convenience, under five general heads, but this classification is an arbitrary one. A single article might properly come under two or more of these heads. The list is prepared from various sources, but particular acknowledgments are due to sources *A* and *B* for partial lists. It is probably not a complete catalogue, but is believed to include all lines of manufacture of any great importance.

METHODS OF MANUFACTURE.

The following descriptions of the methods of manufacture are not to be regarded as invariable in detail in all the producing districts of the United States. It is believed, however, that the general features of manufacture are similar throughout the country, and therefore the methods described may be taken as typical ones. They are selected from official reports made on the industries in the different producing States, and chiefly from reports *A*, *B*, and *C*.

Common brick.—There is a great variation in the quality of brick produced in different localities, due to differences in the clay used and to the care taken in manufacture. Clay carrying a large amount of lime is generally avoided, as this would be made caustic in burning, and, upon subsequent exposure to the weather, would be hydrated and cause the brick to crumble. If the clay contains stone or iron pyrites it is carefully sorted after it is dug and these are removed. It is then exposed to the action of the air in order to weather it and cause it to become partially dry. The disintegrated and air-dried clay is next ground in roller mills and afterward mixed for use. The mixing gives uniformity to the brick, making them equally porous throughout. If the clay used is too "fat" it produces bricks which are liable to bend and crack, and which are not sufficiently porous. If too "poor" the bricks crumble easily. The mixed clay is next taken to the molder. The bricks are molded by the workman upon a bench set before him, in a mold of sheet iron with detached bottom, called the "stock board." The assistant sprinkles the bench with dry sand, and, taking a "clot" from the mass of tempered clay, roughly molds it with his hands into the shape of a brick. The molder takes this "clot" and dashes it into the mold. He then presses the clay into the angles of the mold with his hands, and with the "strike," previously wetted by immersion in water, removes the superfluous clay. The brick is then thrown out of the mold ready to be taken to the drying-floor. In what is called slop-molding the mold is dipped in water to prevent the adhesion of the clay, and the bricks are carried in the molds to the drying-floor. It is said that a molder, with proper assistance, can make 2,000 bricks in a day. In many localities the molding is done by machinery. The molded bricks are set in the yard to partially dry in the sun, and are then stacked in the kilns for burning. The fuel used in burning varies with the locality, but in the large producing districts is generally anthracite screenings. The time required for burning is from four to six days, where coal is used for fuel, and that for cooling down a kiln is about the same.

Front building brick.—The general operations are similar to those followed in making common brick, but a better quality of clay is required, and all the operations are more carefully performed. Pressed bricks are produced by a combination of the hand and machine processes. The molding is usually done by hand, the green bricks being molded larger than the size required, and then compressed to it in a brick press. The molding sand is an important item in making the bricks, as their color and smoothness depend upon it. The molding, pressing, and drying are entirely done under cover, and the bricks are laid on their faces in drying, instead of being put on edge, as is done with common ones. They are put in the kilns with great care, common brick being used to make the arches, and four or five courses of them being laid over the arches before the pressed brick are piled. The ends and edges of the kiln are also covered with pressed brick, and after it is filled common brick are put on the top. The firing is conducted slowly and with care, ten or twelve days being the usual length of time required, and when burned the kiln is slowly cooled. After cooling the bricks are sorted, and defective ones are rejected.

Ornamental and intaglio brick are made in a similar manner, the work being mainly done by hand. More care is required in stacking in the kiln and burning, as they become soft when the firing begins, and are then liable to lose their shape.

Glazed brick.—These are manufactured in Ohio and elsewhere. In Ohio, according to *B*, " the manufacture of glazed brick is already attracting a great deal of interest and attention among architects and builders. The bricks are of various colors, and are employed to make symmetrical and ornamental designs in building fronts. Very striking effects are obtainable through their use. The coloring must, of course, be put upon an ordinary red or light-colored brick, and the proper mixture of reagents to make a good enamel on a red clay is a question for pottery decorators to settle. Some colors are very easily obtained; the yellows are made by using a simple lead glaze on a cheap buff firebrick; blacks are made by a manganese and iron glaze; white and blue are the most difficult to make, as the strong red color, native to the clay, has first to be concealed by an opaque layer of white, which then is finished with a white or blue glaze; green is made in the same way. In the most skillful use of these bricks only a few colors are employed, such as red, black, blue, white, yellow, and possibly green, though all colors can be produced as well as those mentioned."

Roofing tile.—Ordinary brick clay is used in making these tile. At the Akron, Ohio, factories the following method is in use (see *B*): "The grinding and tempering is done in tracers such as used for sewer pipe; when tempered [the clay] is put into a horizontal cylinder, in which a piston is working; whatever is put into the cylinder is forced out, at the end of the stroke, in a series of parallel plates, about 6 inches wide by three-eighths of an inch thick, and extending along until cut up in lengths. Considerable oil is used to keep the clay smooth and to keep the freshly-pressed plates from sticking. These plates are adjusted, one after another, on a series of disks arranged on the circumference of a revolving circular disk. This disk moves through one-sixth of its circumference at a stroke, boring in succession each plate of clay spread out on its table under a compound piston. This piston is arranged to cut off the edge of the plate in a symmetrical shape, and then to press it into the required shape. The pressed tiles are removed and set in piles to dry. Drying takes about two weeks in a steam-heated chamber, as the oil used in the pressing of the clay hinders the escape of the water. They are finally piled in loose order in a kiln, to a depth of about 6 feet, and subjected to a light burn. The kilns employed are circular down-drafts. The ware is of several classes. Shingle tile, which are more like shingles than anything else, are slabs of burnt clay 12 by 6 inches by three-eighths inch, with holes in proper places for nailing them to the roof. Their uses are as nearly like those of a real shingle as well can be. About 5 inches of each tile are exposed to the weather. The so-called diamond tile are made to hook into each other, but are also supplemented by nails. They are more ornamental than the shingle tiles, but as they are more dependent on each other for support they are not so durable or strong. One of the chief objections to a tile roof is its weight; a 10-foot square of plain shingle tile weighs about 1,100 pounds, and the same area of diamond tile weighs from 650 to 850 pounds. The advantages claimed for them are durability, beauty, and immunity from danger by fire or lightning."

Door knobs.—The following method is employed at the East Liverpool works, Ohio (see *B*): "The clays used are the native clays, mainly from the Lower Kittanning horizon. There are two kinds used—a light clay, the same as the yellow-ware clay of this district, several grades of which are mixed to get a good body; and a clay obtained to the southeast of Liverpool, which is naturally red, and which burns to a cherry-red color. These clays, to be properly prepared are put through a process called boiling. The clays are put into a vertical cylinder about 6 feet in diameter, in the center of which revolves a rod carrying stirring and cutting arms, arranged spirally. This machine, filled with the requisite amounts of water and clay, is set in motion by horse power; the clay is beaten to a thin mud or 'slip.' This is then run out in a fine stream into a slightly inclined, oblong box, the bottom of which is covered by a fine bolting cloth. The sand, coarse grit, etc., are passed over the cloth and out at the end to a receptacle provided; the slip passes through into a large tank; from here it is dipped as fast as needed into a large iron-lined pan 20 feet long by 5 feet wide and 1 foot deep. A fireplace and flues circulate underneath the pan and evaporate the water from the slip. One panful a day (about 5 tons) is concentrated. When removed from the pan the clay is as soft and plastic as it is possible to be; it is piled up and covered with wet blankets to keep it tempered. Each color of clay is of course made separately. The clay when ready to use is next 'wedged.' A block of both colors, about 12 by 12 inches by 6 inches is cut and sliced up by a wire into six or eight layers each; these are piled alternately into a new block 1 foot cube. This is then lifted and thrown down with violence to consolidate the layers; it is then cut and welded again by a blow, and so on until the colors are marbled in fine alternating streaks. This clay is then molded into the requisite shapes by first wadding with the hands and then stamping in a die. The knobs are then laid on trays in a steam-heated chamber to dry, and when hardened somewhat are turned to a smooth regular face. They are then dried thoroughly and burned. The burning is done in seggars in kilns like those used in yellow-ware manufacture." They are burned twice; once as biscuit, then dipped in glaze and burned again.

Terra-cotta lumber.—A kaolinite, or clay without grit, unmixed with sand or sandy clay, is mixed with sawdust, worked by machinery into slabs, burned, sawed, and dressed, and in this condition is ready for market. It is claimed that it is indestructible by fire, water, frost, acids, gases, or age. It is a very poor conductor of heat, dampness, and sound, and is said to expand and contract but little under changes of temperature. Its weight is put down at one-half that of brick, two-thirds that of marble or granite, and one-seventh that of iron; and it can be worked with edgetools, bored, and sawed, and holds nails like timber.

Hollow tile, fireproofing, or casings.—This material is known under these different names in different localities. There are two kinds—the first made like terra-cotta lumber by admixture with sawdust, and the second of clay alone. The manufacture is essentially like that of firebrick. It is used to incase beams and girders, to fill in partitions and ceilings, and to cover wood and iron work generally in the construction of buildings.

Firebrick.—While common brick can be made from the poorer grades of clay, containing such impurities as iron, lime, magnesia, soda, and potash, firebrick demand a clay of great purity, and their refractoriness depends in a large measure upon this purity. The reason for this is evident, since if iron, lime, magnesia, soda, or potash were present they would, at the high temperatures to which the finished brick is to be exposed, form fusible compounds with the silica present, and the brick would be destroyed. Makers mix with such pure clay a certain amount, varying with the formula of the individual makers, of calcined clay and coarse sand or so-called feldspar. The clays and flint for the mixture being selected they are thoroughly mixed by grinding them together. This grinding is done in different ways in the districts. A common method is that in which the charge is introduced into a large circular cast-iron pan which revolves on an upright axis. Two or more large cast-iron wheels, which turn on a horizontal axis, are put in the pan. As it revolves the wheels turn and crush and mix the clay. Water in proper amounts is introduced during the operation, and the grinding is continued until the feeling of the mass shows the workmen that the proper consistency has been reached. After grinding the clay is molded, either by hand or machines, like common brick. The hand-made brick are then pressed, in a steel brass-lined chamber, by lever power. The machine-made ones are not pressed. The pressed brick are now dried, either in covered sheds in the open air or in chambers heated for the purpose. After they are sufficiently dried they are piled in the kilns, being separated from each other by layers of non-vitrifiable sand. The time required for burning is about six days, and the firing is conducted with the utmost care, as upon it the perfection of the brick largely depends. A low fire is used at first, increasing gradually until the proper temperature is reached. The fires are kept at this for several hours and are then drawn, and the kiln is allowed to cool for three or four days before opening. The kilns used are of various kinds, some makers preferring up-draft and some down-draft, and their size depends on the extent of business carried on.

Gas retorts.—The clay used in making these retorts must be able to stand strong heat without tendency to soften, since they have to sustain their own great weight and also that of the charge they contain. Great care is exercised in compounding the mixture from which they are made. The failure of a retort would entail a considerable loss aside from its own cost. Calcined clay is used in large amounts, but it is more finely crushed than for firebrick and requires a very good and plastic bond clay. The retort is shaped from the tempered clay by filling the space between a large sheet-iron shell and a wooden core. The shell is placed in position and the floor covered with clay 4 inches deep and tamped. The core is then introduced and adjusted so that it is separated from the walls on all sides by a space of 4 inches. The clay is then filled in in small amounts and gently tamped. When the retort is high enough, the core is withdrawn by a crane and the mouth of the retort is made by hand. The shell, which is made in two sections, is then unbolted, and the finished retort is left standing on end. It is left in this position to dry for several weeks and is finally removed to the kiln to be burnt. Burning is done in ordinary firebrick kilns, and bricks are piled about the retorts to keep them in place, and from sagging. Retorts for zinc works and for other similar purposes are built in like manner.

Glass pots.—The following method is in use at the Ohio Valley Pot Clay Company's works at Steubenville, Ohio (see *B*): "The clays used are (1) Gros Almerode, near Coblentz, Germany, for bond clay; (2) Christy clay, from near Saint Louis, Missouri, used for calcine and bond; (3) Blue Ridge, Missouri, clay, used for bond and calcine; (4) Mineral Point, Ohio, flint clay, used as flint and calcine; (5) old pot-shells, used for calcine. The German clay is shipped as ballast in the holds of vessels, and hence transportation costs but little—much less than for the Missouri clays, in fact. It is an excessively fine-grained and heavy clay and is very plastic, making a better bond than any native clay. It comes in blocks 9 by 6 by 6 inches, which have to be pared with a drawknife and then broken and inspected and all irony spots removed. No pieces larger than a walnut are allowed to go into the mixture. The work involved in getting this clay ready for use is excessive, and it is the opinion of those at the works that it is much overrated. It is an excellent bond clay, it is true, but its refractory properties are excelled by the Christy clay of Missouri. These Missouri clays come in blocks either calcined or raw. They are pared and broken, but are not sorted over. They are washed before shipping, so that they are much finer than in nature. The Blue Ridge is the finer grained of the two. The Mineral Point calcined clay is not now largely used, because the extensive connections of the company allow them to get back their old pot-shells for calcine, which, being already in the desired composition of the mixture, make a better calcine than any single clay. These shells are chipped with small hammers until no part of the surface remains and only the clean interior is left. The charge is composed quite largely of calcine, with a little flint clay, and the remainder German and Missouri bond clays. The mixture is ground in a dry pan and sifted by a jig bolt, and the coarse part is reground. It is then pugged five or six times in succession and then is stored and blanketed. It remains in this state until it sours and smells offensively, which the men claim is necessary to its proper working. It is wedged by hand and is ready for use. The pots are large structures, about 5 feet high, 4 feet wide, and 4 feet long, bounded on top and sides by covered walls and on the bottom by a flat face. They weigh from 2,000 to 3,000 pounds each, and sometimes as much as 3,500 pounds. They are made from 3 to 5 inches thick, with a thicker floor, and are each built on a flat platform covered with gravel, so that air may circulate beneath them and dry them faster. They are built entirely by hand, small pieces being added daily, and are left to harden before another addition is made. Each builder, of whom there are four, has on hand twelve or fifteen pots at once, on which he daily builds a little more, until at the end of three weeks or a month he finishes them altogether. About sixty pots a month is the average output. They are dried from one to six months—the longer the better—and are shipped on three-wheeled trucks, so that they are loaded and unloaded with ease and security. Each pot is worth from $60 to $75. The quality of the ware is excellent, and it has a wide consumption among glass workers."

Stove and furnace linings.—These are ordinary firebrick, molded into the shapes required.

POTTERY.

Before giving the methods used in manufacturing pottery it is necessary to define the various kinds given in the preceding list, made in this country. The compact and concise definitions used in *B* are quoted: "Stoneware is the product of an unmixed natural clay, burned at high enough heat to oblige the impurities to combine with free silica, and thus cause an incipient vitrification or fretting, without loss of shape. It should be impermeable to water without any glazing on it, but it frequently fails in this point. Its color is bluish gray and is due to combined iron." "Earthenware is a product of very similar clays burned too lightly to vitrify the body or combine the iron; it is of a yellow or red color, from the free iron, and is porous unless glazed." "China (the ironstone china made in this country) is a mixture of several clays with powdered silica and enough potash feldspar to make the body vitreous on burning. Porcelain is made in the same way, but in very different proportions of material; white ironstone china is thick and opaque; porcelain is often as thin as an egg shell and nearly clear enough to be called translucent. China is of a dead or bluish white color, while porcelain is of a creamy-white tint."

Stoneware.—According to the census of 1880, Ohio is the largest producer of this ware, and it is therefore fit that the methods in use there be given (see *B*): "The operations are: (1) Wetting the clay; (2) grinding; (3) wedging; (4) turning; (5) drying; (6) slipping; (7) burning; (8) sorting the product. In very many places the clay is put in a bin before using, and allowed to stand over night after drenching with water. This precaution is well taken in small works, where horse power only is used in grinding; in the largest steam works it is unnecessary. The grinders for stoneware clays are of several kinds; the simplest is a pugmill. The next machine has no specific name, but is the one in use in all the country potteries. It is a square frame pivoted on an upright beam, which runs through the point of crossing of the diagonals, on the projecting ends of which are fastened cart wheels, which work in a circular trough beneath. The whole frame revolves by the motion of a large frame above, which receives its power from the horse or engine; the motion is slow, but by weighting the corners of the frame the wheels in their revolution manage to cut the clay to pieces quite effectually. Such a machine, which can easily be made by any village mechanic, can grind from 1,200 to 1,500 pounds at a charge, and will occupy about two hours in doing it. This amount of clay will make from 180 to 190 gallons of ware. The clay, after grinding, is balled into large masses and wet-blanketed to keep until used. The grinding is done in the Akron district in steam mills called tracers. They are very efficient for stoneware clays, grinding about 1,200 pounds to a charge in from sixty to one hundred minutes. The clay, after being ground, is put through a process called wedging" [see method of making door knobs for description of wedging]. "This treatment is supposed to eliminate blebs, or spaces in the clay, and any larger pieces of foreign matter. When wedged it is rolled up into wads or balls which have a definite weight for each kind of ware, and is then ready to be turned." Turning will be described later under whiteware. The articles made are crocks, fruit jars, jugs, milk pans, churns, etc. As fast as the ware is made it is dried. In small potteries this is done in the sun, but in the larger ones the ware is piled on shelves in a room artificially heated. The dry ware is next "slipped." This term means the covering of the ware with any wash or solution. The slip used with stoneware is made by stirring a very fine-grained clay into water. The ware, when dipped in this, receives a thin coating of the suspended clay, and this coating, when heated in the kiln, vitrifies and gives a glassy surface. The color of the glaze depends on the composition of the clay used in the slip. That containing alkalies and alkaline earths only with silica would give a light-colored glaze, while that containing iron would give a darker color.

Earthenware.—The character of the clays used in making earthenware is nearly the same as that used for stoneware. In some places the same clay is made into both kinds of ware, the only differences between them being in the processes employed. Generally, however, the clay for earthenware should carry less sand and any iron present should be disseminated uniformly through it. The clay is allowed to slack in the air, after mixing, for a time sufficient to partially weather it. It is then washed. Various methods of washing are in use. The one given below is that employed to some extent in preparing pottery clays in New Jersey. It is quoted from *C*: "Clay stirred up in water will remain in suspension a long time, while sand, gravel, and nodules of iron pyrites settle quickly. The finer the clay is the longer it will remain suspended in water. Advantage is taken of this property in washing the clays and freeing them from impurities. Washing has the further advantage, too, of bringing the clay to a uniform tint or color. As taken from the bank it may be streaked with brown, yellow, or red colors, or with all of these, but after passing through the washing process these colors are all blended in one uniform tint. And by a proper selection of the white and stained clays a great variety of colors is produced. The apparatus for washing consists of a large trough or bin into which the clay from the bank is dumped, covered with water, and allowed to stand for twenty-four hours. Other large troughs, in which long horizontal shafts annexed with knives revolve, receive the clay. The knives are set at right angles to the shafts and are fastened in a spiral line, so that at every revolution of the shaft the clay in the whole length of the trough is thoroughly stirred up and mixed with the water which is constantly streaming into it. Large vats are used in which to receive the clay and water. These vats are made of puddled clay at the bottom, which is then covered with boards. The sides are made of a double casing of boards filled in with puddled clay and backed up with earth. They are nearly 4 feet deep. There are a number of vats, entirely separate from each other, which are intended for white clays and different shades of colored clays. Each vat has also partitions or guiding boards in it which are so arranged as to cause the water with the suspended clay in it to circulate between them and cross the vat repeatedly before it reaches the farthest part, and so that the clay may have time to settle and let the water run off clear at last. When the washing machine is in operation a constant stream of water is run into it and is thoroughly mixed with the clay, which is thus divided into its finest particles and separated from its heaviest impurities, and only that which is fine and completely suspended in the water can run off into the settling vats. The process of washing any desired quality of clay is carried on from day to day till the deposit in the vat is thick enough to handle conveniently and to furnish a supply adequate to the demand. The washing of clay is common in all kaolin districts where clays for ware or paper are obtained, and also at potteries as a further preparation for their use in the body of the finest whiteware. These modes involve various styles of machinery whereby the clay or kaolin is agitated with water, and then the clayey liquid is conveyed to a series of settling vats. There may be many modifications in the mechanical arrangement of these appliances for stirring the clay, as well as differences in the size and forms of the vats. The washed clay is allowed to dry in the vats on long exposure, or the water is pressed out of it by subjecting it to great pressure in bags. The latter method obviates the length of time required for drying in the open air and does not need such large vats."

After the clay is pressed it is rolled in a wad, and, still in a moist and plastic condition, is put in a close room and piled, and covered with blankets until it is used. The next step is "wedging" or "slipping," already described. After wedging, the clay is ready for the potter. According to *A*, "there are three methods of fashioning the innumerable and various articles made from clay. The first and most ancient is that of throwing, in which the thrower or jigger throws down a lump of clay upon the revolving table of his lathe. Using both hands he works the lump into the shape of a rude cone, and then flattens the mass within a few inches of the table, the object of his operation being to force out any air bubbles that may remain in the clay. By means of his hands and fingers, and referring continually to measuring sticks, he fashions the vessel according to a model or after his own fancy." The above is the method most commonly used in making earthenware, but in this connection the remaining ones are given. They are mainly employed in making whiteware and porcelain. "Few jiggers are employed in our potteries [the Trenton whiteware potteries], the best examples of this art being found in the county earthenware potteries. Presswork is the method commonly employed. This work is done in molds made of plaster-of-Paris, one-half of the pattern being formed in one side of the mold and the other half in the other side. The two molding pieces are then accurately fitted together. Handles are molded separately and fastened on with slip. Handles of teapots, fluted solid rods, and all such slender ornaments, are made by forcing clay under great pressure through a narrow hole in the bottom of a piston previously charged with dough clay. As the thread of clay issues it is cut into suitable lengths. From these pieces the ornaments are bent and fastened on with slip by the handlers. For articles of very irregular shape a method called casting is employed. The two halves of the mold are fastened together and slip is poured in until the cavity is quite full. As the molds are previously thoroughly dried, the absorbent power of the plaster soon abstracts the water and makes the coating of the clay next to it stiff and doughy. When the liquid is poured out this doughy coating remains. If each half has been cast separately, as is the usual practice, the halves are allowed to dry to the green or most tenacious state and are then joined with slip. The method of casting is that usually employed in molding porcelain. Another method of forming articles in porcelain we may call the crush method. The dough is spread with a rolling pin upon a moistened sheepskin, and is transferred over the mold by lifting it carefully upon the skin. All pieces, whether pottery or porcelain, are finished upon the lathe when they have dried to their greatest tenacity. A moist sponge and a knife are the implements used in turning."

The ware now being formed is next put in seggars for burning. Seggars are vessels of fireclay, in which all articles except the most common earthenware are burnt. They are made of clay slabs, roughly cut with a spade and worked with a mallet over an oval form. The bottom is put on separately and the seggar is burnt before it is used. In earthenware making the seggars are filled, the pieces being separated from each other by pins or cockspurs, and the covers are luted on. They are then piled in the kilns one above another. After the kiln is filled the openings are luted and the fire is started. The fire is started slowly and gradually raised; the firing generally occupies about forty-eight hours and about the same time is required in cooling down. When cool the seggars are removed and the biscuit taken out. This biscuit is very porous and when dressed of all rough prominences is ready for the glaze. The seggars, if uncracked, are used again. Both the New Jersey and Ohio potteries use New Jersey fireclay for seggars. "The theory of the glazing of pottery is very simple, but in its application lies the excellence of one ware over another. There are certain substances that have the property of fusing under heat in the presence of free silica to a clear, transparent silicate, of which glass is the type. To make a potter's product useful it must have its tendency to absorb liquids removed, which is done by wetting the biscuit ware with a substance which will fuse to a clear glass with the silica of the clay and give a smooth, imperishable finish to the work." There is a large range of bodies chosen to do this work, notably the alkalies, borax, lead, etc. The glazes applied to yellow ware are usually made as follows: Portions of litharge (PbO), flint (SiO_2), spar (potash feldspar), and Paris white ($CaCO_3$) are mixed in a grinding vat with a thin slip of pure clay. This last is necessary to keep the heavier bodies from settling out. All the elements being well incorporated the mixture is transferred to the glazing trough and used; heat, of course, on such a mixture (silica and lead, potash, and lime, with a little clay) would immediately produce a very fluid, clear glass. Sometimes the carbonate of lead is used instead of the oxide, but the effect is the same. These are the main elements of a yellow-ware glaze. The special proportions used are kept secret by each potter, and even the constituents by many, though these may easily be determined by looking over the list of bodies which would exercise the desired action. Some glazes will crack over the surface of the ware and greatly disfigure it, and a change of proportion or working is necessary to correct this tendency. Rockingham ware is the same as yellow, except in color; the addition of a large amount of manganese oxide is made to the ordinary glaze, and the ware, first given its ordinary glaze, is then sprinkled or "spaddled" with the manganese glaze. This, on burning, colors the otherwise clear glaze to a beautiful brown, running to black. "Self-rock" or brown ware is made by the use of a manganese glaze over the whole surface, instead of sprinkling it.

Whiteware and porcelain.—To quote Mr. Orton again: "The main distinction between the yellow ware and whiteware manufacture is in the preparation of the clay 'body.' This 'body' or mixture of clays, flint, and spar, to be used in the molds, is the great secret of each establishment. Usually not more than one or two men in the works know it. The clays chosen are selected with reference to plasticity, shrinkage, liability to crack, color, etc.; in a mixture at least one light clay is employed, and the aim is to keep the mixture of clays as light in tint as may be and still secure the other qualities necessary. The flint is used in the finest state of division and is perfectly white, as is also the spar. The body mixture of kaolin alone would, if heated, be liable to crack without apparent cause and would be infusible at the heat applied. By adding silica, which sometimes forms nearly one-half the mixture, the body is very much whitened and the clay is much more like a stoneware clay in composition, and is prepared to vitrify on heating, but because of the purity of the reagents there is nothing present to cause vitrification with the free silica. Should this body be burned all tendency to shrink or crack would be gone, but the bond would be very slight which would hold the mass together; a blow on a thin edge would give a dull wooden sound, which well illustrates the lack of close union of the particles. By adding spar (which is powdered orthoclase, containing 14 per cent. potash) the mixture is complete; the color is corrected by the flint, as well as the tendency to shrink and crack, and with the presence of the spar the burning immediately causes a thorough vitrification of the whole mass to a homogeneous solid with a slightly glassy fracture. A blow now would give a clear ringing sound. As there is necessarily some small amount of iron in the clays used, its yellow color is usually counteracted by the use of a very little cobalt. The blue and yellow colors really unite to produce a green, but this color has not nearly so strongly marked a character as either of its constituents, and escapes observation."

The process of preparing porcelain paste is much the same as that employed for whiteware paste. The grinding of the feldspar, chalk, broken porcelain, etc., which enter into the composition of the paste, must be well done and all particles of iron, mica, and other foreign substances must be removed. The ingredients are mixed either in the form of slip or in the dry powder, the latter being the least convenient method but most accurate. The composition of the best Sevres porcelain is—

	Per cent.
Silica	58.00
Alumina	34.00
Lime	4.50
Potash	3.00
	99.50

The methods of mixing and forming the ware have already been described. The placing in the kiln and firing are the same as in earthenware; but only a single article of porcelain paste can be burnt in a seggar, and the bottom of the seggar must be sprinkled with infusible quartz to prevent adhesion between it and the porcelain. After firing the biscuit is ready for the glazing.

"The glazes used in whiteware are much more complicated than for yellow ware and require perhaps the most skillful work of all to get just right; there is more value placed on the composition of a good glaze than any secret about a pottery, even including the composition of the body. The constituents and way of mixing an ordinary glaze are as follows: Proportions of borax, or boracic acid, or both, with flint, spar, clay, and Paris white, are mixed while dry and put into a seggar, which has been previously coated with a wash of flint. This precaution is necessary because the liquefying of the glaze would allow some of the iron from the seggar clay to color it if it were not protected by the pure silica. On heating, the mixture becomes a clear glass, which is called 'fret.' This fret is ground up and mixed with fresh proportions of Paris white, carbonate of lead, flint, and spar, and is put into a grinding pan or vat lined with French buhrstone. In this it is ground into a thin slip of pure, white clay, as something of this sort is necessary to incorporate the heavy parts of the mixture and keep them from settling out. The most common difficulty met in glazing is the tendency of the polished surface to crack or 'craze.' This is due to a lack of adjustment between the coefficients of contraction of the body and glaze, and in the proper adjustment of this point lies the hardest problem of the potter. Other troubles are also known; if a seggar leaks or admits air while hot, it causes the ruin of everything in it, for the sulphurous gases of the kiln immediately attack the hot lead silicate, causing a sulphide film to form on it, which is black and unsightly.

"The whiteware made in our potteries is graded as: (1) Ironstone china; (2) majolica; (3) 'C. C.' ware, a grade of whiteware made from poorer clays and cheaper and inferior. China differs from majolica much as yellow differs from Rockingham ware, in finish and glazing only. The glazes used in majolica are applied after the first or body glaze, in a soft, pasty state and in dabs, which would presage a very rough appearance when finished; but on heating they melt and flow over the ware, making an effective play of color. The colors used are in the glaze and differ from all other styles in being neither beneath nor above it."

In the decoration of glass, pottery, enamels, etc., "the coloring agents employed are the metallic oxides, these being the only bodies whose coloring effects would last at the temperature used. The forms in which these oxides are used are called enamel paints, and are mixtures of the requisite oxide with suitable bases and fluxes, so that, on heating, the latter unite to form a glass which receives its color from the accompanying oxide. The oxides in commonest use are cobalt, blue; nickel, yellow or brown; iron, black; manganese, brown or violet; chromium, green; copper, red; tin, pink; tin and gold, purple; silver, or uranium, antimony or carbon, different yellows; zinc, opaque white; and gold, purple." There are several well-marked styles of pottery decoration now used, such as painting, striping and hand-painting, and printing.

The decoration is usually placed upon the already glazed ware, but some underglaze work is done in the Trenton potteries.

China clay, or kaolin, is used to a considerable extent in making cheap pigments and as a weighting material or adulterant.

Ornamental terra cotta.—The clay used is a gritty, plastic one, and no special care is taken in preparing it, save that it is thoroughly ground. Terra cotta proper burns in the kiln to a hardness that gives the articles, when struck, the ring of iron. The clays used are more or less largely colored with oxide of iron. According as this is present in greater or less color the ware produced is red, buff, or brown in color. When single pieces are required the molder makes his design in clay, which is dried and fired. When a number of similar ornaments are wished molds are prepared in plaster. The clay is pressed with the hand into the mold, and the objects are afterward finished by hand. The burning of real terra cotta should be done in a closed chamber, so that the ware is not in contact with the fire. The objects to be burned are placed in tiers, the layers being separated by firebrick. Terra cotta is used for making chimney tops, outside and inside ornamentation for buildings, lawn vases, statuary, etc.

Encaustic or enameled tile.—According to *B*, "this ware is manufactured in only three places in the United States at present, among which the works at Zanesville were the first to be established, and their wares have attained as high a grade of perfection as any." "Our best tiles are as good as the best of the English and French, but the average of foreign tiles exceeds the average of the home manufacture. The clays used are of many kinds." The body clays are found near Zanesville, but parts of the mixture are obtained from abroad. "In making colored clays the effort is to obtain a clay as nearly right naturally as possible, and then to correct it with the necessary reagents, rather than to undertake to establish a new color in a clay. The process in outline is as follows: The clays are washed or beaten up to a slip in a 'blunger,' and while in this state the necessary metallic oxides are added to color them. The slip is strained and evaporated to a paste in iron-lined tanks. The paste is stacked up in open cribs in a tight steam-heated room, and the clay is there retained until perfectly dry. It is then reduced to powder and uniformly moistened, but so slightly that it is not perceptible to the hand, and in this state it is molded. Each kind of powder, though probably indistinguishable in appearance from others, has the elements in it which will develop its own color. The simplest tiles are made from clay of one color, and the process consists in stamping so much clay powder into a confined space, and consolidating it by enormous pressure. Next come those tiles made of two-colored clays; the first stamping makes the body, but leaves indentations in its surface, into which the second clay is put, and this is pressed into place; the tile is then scraped to get a cleanly-drawn line of both colors and again stamped with a flat die. The most complex tiles show six colors on their faces, and have a band of a seventh kind of clay running through the center to keep the complex mixture from warping. They are dried in steam-heated closets for as much as six weeks after forming, in order to insure their perfect dryness before burning. The burning is done in seggars, like chinaware, and with fully as much care." "The tiles are sold in the biscuit state, or are glazed, plain colored, or majolica."

Sewer pipe.—Ohio produces more of this pipe than any other State, and the following methods are used there (see *B*): "There are two quite well-marked ways of making sewer pipe, which lead to their classification usually as the river process (that used in the Ohio valley in Jefferson county) and the Akron process (used at Akron and Columbus.)" In the river process the grinding and tempering are done as in the manufacture of firebrick, but the clay is dried, ground, and screened before going into the wet mill. "When the clay has been ground, sifted, and tempered it is usually elevated by a belt to the upper story of the works, and deposited in a bin beside the top of the press. These presses are the most expensive part of a sewer-pipe plant." They are of different kinds, but all act on the same general principle. "The press consists of a large steam cylinder upon a high iron frame; the piston runs into a second cylinder of much less diameter situated beneath it; this is called the mud-drum or mud cylinder, and into it the clay to be pressed is introduced, and from its lower end is forced out as pipe by the pressure from the upper or steam cylinder. The piston at the upper limit of its stroke leaves a passage into the inside of the mud-drum, near the top, which is closed as the piston moves farther down. Into this opening is shoveled the tempered clay. It is tempered so dry that it may be shoveled with perfect ease and it has no tendency to stick together by contact alone, though it does so readily by pressure. The cylinder being filled with clay, the piston is given steam and moves down slowly, consolidating the clay and expressing the inclosed air through small holes in the piston head and the cylinder bottom. When the clay begins to issue through these holes the pressman knows that the clay has filled the shape of the cavity perfectly; and as the bottom is a movable one, it is loosened and dropped upon a balanced platform close beneath it. The platform under the weight of the cylinder head, which is so shaped as to form the pipe, is just counterbalanced and by any pressure can be moved up or down, carrying the socket shaper on its top. The bottom being pushed out of the way continued pressure from above causes the pipe to issue. When enough has come out it is cut off by a rotary knife from the inside and the separated length of pipe is carried away either on a cart or in the hands. It is next sponged and pared to smooth it. The pipe is shaped by being forced out between the wall of the mud-drum and a conical core which is suspended from higher up in the drum. This cone parts the clay evenly on all sides and causes it to leave the press in an even, regular shape and thickness."

"The heat used in sewer-pipe burning is only that necessary to get a good salt glaze; about one barrel of salt to a kiln is required. Coal is the fuel invariably used. The finished pipes, after some coating, are stacked up in piles ready for sale. The fittings which go with the pipe, such as curves, elbows, traps, Ys, and Ts, and all the other special shapes, are made by hand in plaster molds."

In the Akron process the clay used is very different and the grinding is done in machines called "tracers." "The ground clay is shoveled into a squeezer, either of the screw or piston type, and it is concentrated into a long, compact cylinder about 6 or 8 inches in diameter. This is cut into lengths of about 15 pounds weight and is fed to the machine in this shape. From this results the worst trouble of the Akron pipe; the stiffness of the clay and the large, well-compressed wads in which it is fed act together in keeping the clay from uniting in a homogeneous mass." The making of the pipe is done in the presses already described. The kilns used for burning are similar to those used in stoneware manufacture, and the burning requires about six days.

Drain pipe or tile.—Almost any clay that will make a good brick can be used for drain pipe. The clay is wet down after being dug and then ground. A common form of grinder has two parallel horizontal rolls, which revolve toward each other, a small space (about a quarter of an inch) intervening between them. "On the surface of these rolls are small, gradual depressions and elevations which are arranged on both sides of the center as spirals toward either end. Any particle of hard matter half an inch in diameter will not catch on the smooth, slippery roll, but by the spiral motion of the alternating ridges and depressions will be carried off on either side and dropped into an appropriate receptacle, while all clay and soft matter is crushed and deposited on the belt which runs underneath the machine. On this belt it travels to the auger machine, into which it is delivered.

"The grinder is run at high speed and has no trouble in cleaning enough clay for one large machine to use. The auger machine consists of a cylindrical shell of iron plate, inside of which works a screw or auger. A hopper at one end catches and collects the clay as it comes from the grinder, and it is dropped upon the revolving screw; it is caught up and carried forward and is soon forced out at the other end through the orifice in the die. The machine has a set of dies of from 2 inches to 12 inches and can make any size at will. Besides the circular tile, by alterations in the die, fireproofing, square tile, perforated brick, etc., can be made. There are a great many styles of auger machines in use. The shaped clay issuing from the machine is cut into lengths and put on the shelves of an elevating belt. It is received on the upper floors and set on end on the drying floors." The tiles are then dried and burnt.

LOCALITIES OF MANUFACTURE, AND PRODUCTION STATISTICS.

It is not possible to give the statistics of production of the various articles mentioned in the preceding list or to mention all the localities where the different manufactures are conducted. According to the census of 1880, the value of articles manufactured in the United States from clay during that year was over $40,000,000, and over 75,000 men were engaged in their manufacture. The figures of this census do not, however, represent the present production of the country. There has been a great increase in production in many lines of manufacture, and these figures do not approach present facts. As illustrations of this the following comparisons will be instructive:

In 1880 the value of the manufactured products, including common brick, firebrick, pressed brick, tile, drain tile, and miscellaneous articles in the State of Illinois was given as $3,065,300. In 1883 the same State produced drain tile alone valued at $3,960,958. In 1880 the entire production of drain tile in the United States was valued at $1,765,428.

New Jersey is credited in 1880 with producing, under the same heads given for Illinois, articles valued at $1,672,533. In 1883 her production was valued at $2,936,047.

Numerous other illustrations might be given, but the above examples show the growth of these industries during the three years immediately following the census.

Following the arrangement previously given, the notices of manufacturing localities and such statistical information as is obtainable are as follows:

EASTERN DIVISION.

Common brick.—The distribution of clays suitable for common brick is so wide and they are so generally made in all the States that no extended notice can be made of the localities producing them. Most of our large cities and towns have near them places of manufacture to meet the local demand. The figures given below are nearly all obtained from various State reports for 1883 and previous years. While they do not give any definite information as to the total production, they still show that of some of the more important districts and give some idea of the magnitude of the industry.

In 1880 the total production of common brick in the United States was 3,822,362,000. In 1880 New York produced 575,996,000 brick. In 1883 New York produced as follows in the Hudson River district:

Production of common brick in the Hudson River district, New York, in 1883.

Localities.	Number produced.	Localities.	Number produced.
Haverstraw	311,396,000	Hudson	8,000,000
Verplanck's Point	73,750,000	Athens	8,000,000
Fishkill	53,250,000	Coxsackie	5,000,000
New Windsor	35,000,000	Between Coxsackie and Albany	10,000,000
Rondout	64,000,000	Between Albany and Troy	30,000,000
Glasco	27,500,000		
Catskill	32,250,000	Total	658,146,000

There are 142 yards in this district. Its production in 1884 is estimated at 775,000,000. The production for the remainder of the State is large, but figures cannot be given.

Production of common brick in New Jersey during the year ending July 31, 1883.

Localities.	Number of brick made.	Value.	Hands employed.
Hackensack river	31, 500, 000	$220, 500	211
Raritan and South rivers	84, 000, 000	588, 000	676
Raritan bay and Matawan creek	18, 000, 000	126, 000	190
Trenton and Kinkora	32, 900, 000	398, 200	578
Delaware river, Pea shore	8, 000, 000	64, 000	100
Camden county and South Jersey (*a*)	6, 000, 000	42, 000	75
Scattering throughout the State (*a*)	6, 000, 000	42, 000	75
Total	186, 400, 000	1, 480, 700	1, 905

a Estimated.

The production of common brick in New Jersey during the calendar year 1884 is estimated at 225,000,000.

Production of common brick in Pennsylvania in 1883.

Counties producing largest amounts.	Number of establishments.	Wages.	Number of brick made.	Hands employed.
Allegheny	8	$65, 557	19, 373, 000	164
Berks	8	25, 772	11, 580, 000	174
Dauphin	8	50, 496	10, 250, 000	177
Philadelphia	39	800, 962	176, 752, 000	2, 296
Total for the State	160	1, 190, 244	292, 512, 740	4, 092

The production of common brick in Pennsylvania in 1884 is estimated at 325,000,000.

In 1880 Ohio produced 296,224,000 brick, and had from 375 to 400 establishments. In 1884 the production was not less than 325,000,000.

Production of common brick in Indiana.

Years.	Number of establishments.	Capital employed.	Value of product.	Hands employed.	Wages.
1879 (*b*)	406	448, 200	995, 310	1, 928	....
1882	173	346, 550	993, 425	1, 357	$359, 870
1883	396	861, 872	2, 170, 277	3, 012	....

b Estimated; evidently too high.

The District of Columbia produces annually about 100,000,000 brick, and in 1884 the production probably reached 120,000,000. The clay beds at Washington are in a continuation of the clay belt which extends through eastern Pennsylvania down through Delaware, Maryland, the District of Columbia, and northern Virginia. Brick made from this clay are noted for their great hardness and cherry-red color.

Pressed brick.—According to the census of 1880 the total number of pressed and ornamental brick made in the United States in that year was 210,815,000. These brick are largely manufactured at Philadelphia, Baltimore, Washington, Chicago, and Milwaukee. The pressed brick made at Philadelphia and Baltimore are made from the clay contained in the belt just mentioned. Ohio produced 10,365,000 in 1880, her chief center of manufacture being Zanesville, Muskingum county.

Hollow brick are made to some extent in the Raritan River district, New Jersey, and glazed brick are made in Ohio.

Roofing tiles are manufactured at Akron and Cincinnati, Ohio, the largest works being at Akron; and also on the Raritan river, New Jersey.

Door knobs, hardware, porcelain, and telegraph insulators.—These articles are chiefly made at works which produce whiteware pottery. There are two establishments at East Liverpool, Ohio, which make them, and several more at Trenton, New Jersey. The Liverpool works turn out about 30,000 a day.

Terra-cotta lumber.—The only establishment, so far as reported, producing this material is at Perth Amboy, New Jersey. It has not been successful as a business venture.

Fireproofing or casings.—A large amount of this material is manufactured in Middlesex county, New Jersey. The casings made here are used in the construction of buildings in New York and adjacent cities. Pennsylvania produces a large amount, and considerable is made at Toronto and Columbus, Ohio.

Firebrick.—Pennsylvania, Ohio, and New Jersey are the three States producing the largest amounts of these brick. In 1880 Pennsylvania produced more than any other single State, and Ohio ranked next, producing 19,878,000 in that year. Ohio made about 25,000,000 firebrick in 1884. During the year ending July 31, 1883, there were made in New Jersey 20,500,000 firebrick, valued at $508,250, and 600 men were employed in the manufacture. For the calendar year 1884 the output is estimated at 20,000,000. No complete returns can be given for Pennsylvania for 1883. The chief centers of the industry in that State are in Allegheny, Berks, Cambria, Centre, Clearfield, Lehigh, Beaver, Philadelphia, and Somerset counties. In eighteen counties of the State there were in 1883 forty establishments making firebrick, employing 1,729 hands, and paying out $664,994 as wages. The number of brick produced cannot be given with exactness, but would exceed 55,000,000 in 1883 and reach 50,000,000 in 1884.

Retorts and glass pots.—At Steubenville, Ohio, is a large factory devoted to glass-pot making, and there is one other in the State. In addition several glass works using these pots in large numbers make their own supply in that State. In New Jersey glass pots are made at the glass works, and the same is probably true of the Pennsylvania glass district. There are two factories making gas retorts in Ohio—one at Cincinnati and the other at Dover.

Stoneware and earthenware.—The manufacture of these different wares is widely distributed throughout the United States. Potteries producing ordinary stoneware are to be found in all regions producing clays, and local demands are largely met by them. Earthenware is not so generally manufactured, the principal points of production being in Ohio and New Jersey, where it is made in connection with the whiteware manufacture. According to the census of 1880, there were in the United States in that year between 600 and 650 potteries making stoneware and earthenware, producing annually about $3,000,000 worth. The largest amount is made in Ohio. The centers of the stoneware manufacture in this State are at Akron and Roseville, while earthenware is chiefly made in Columbiana and Hamilton counties. In 1882 Ohio produced stoneware valued at $205,995. Her earthenware potteries, nine of which are located at East Liverpool, one at Wellsville, and several at Cincinnati, produced in the same year goods valued at $419,000. Pennsylvania produces large amounts of stoneware. The statistical report of the State for 1883 does not furnish the data necessary for a complete statement of the production of this industry, but from the partial facts given it appears that in 1883 there were in the twenty-one counties that produce the largest amounts 39 potteries, employing 683 men, to whom wages amounting to $231,022 were paid. The value of wares made is not given in all the counties. In 30 of the potteries the value of ware is put at $441,535. The counties producing most largely were the following:

Production of stoneware in the leading counties of Pennsylvania in 1883.

Counties.	Number of establishments.	Hands employed.	Total amount paid in wages.	Value of annual product.
Beaver	6	232	$83, 330	$167, 000
Cambria	1	15	6, 800	18, 000
Chester	4	121	33, 700	81, 800
Greene	2	69	18, 433	....
Philadelphia	5	167	66, 300	142, 600

The census of 1880 rates the States engaged in manufacturing these wares in the following order, according to amount of capital employed: Ohio, New Jersey, New York, Pennsylvania, Massachusetts, Illinois, and Maryland. The more probable arrangement would be Pennsylvania, Ohio, New York, New Jersey, Massachusetts, Illinois, and Maryland, as in the census rating whiteware is also included, and Ohio and New Jersey produce this largely.

Whiteware.—There are only two States which produce any considerable amounts of ironstone china, whiteware, or porcelain. These are Ohio and New Jersey. The industry in Ohio is carried on chiefly at East Liverpool, with a few potteries at Wellsville, near Liverpool, and several at Cincinnati. In 1883 there were thirteen firms using sixty-three kilns at East Liverpool, two firms at Wellsville, and a number at Cincinnati. The potteries in New Jersey are all at Trenton. In 1883 there were twenty-three firms, using one hundred and ten kilns, making ware there. The census of 1880 gave $5,000,000 as the annual value of goods of this grade made in the United States, and the number of kilns employed was put at about two hundred. These figures did not include decorated ware or printed goods, but covered plain white, C. C., and ironstone china only. Of this amount Trenton is to be credited with about $3,725,000 worth, East Liverpool $800,000, Cincinnati and other points the remainder. In 1882 the value of whiteware, etc., produced in Ohio was $1,250,400, of which East Liverpool produced about $800,000. The following table shows the production in New Jersey in 1880 and 1883:

Production of whiteware in New Jersey.

Years.	Whole number persons employed.	Capital employed.	Wages paid.	Value of product.
1880	3, 195	....	$1, 225, 775	$2, 936, 047
1883	3, 250	$2, 990, 000	1, 577, 000	3, 725, 000

Most of the whiteware made in these States is of the cheaper grades, and undecorated; but there is an increasing production of finer wares and decorated goods. At Trenton, potteries which three years ago employed two or three decorators now employ from twenty to fifty, and quite a business has grown up in decoration by those who do not manufacture the ware. The same is true of the Ohio potteries. The clays used at the Trenton potteries are a mixture of the kaolin of Delaware county, Pennsylvania, and similar clays from the State of Delaware, with the plastic clay of Middlesex county, New Jersey. The Ohio manufacture is an outgrowth of the yellow ware manufacture, and dates back only to 1873. All the materials for whiteware used in that State are brought from other States, no clays being yet developed there suitable for the purpose. The kaolin beds of Chester county, Pennsylvania, Maryland, Delaware, Indiana, Missouri, Virginia, and South Carolina, all furnish some material, and much clay for the cheaper wares is brought from New Jersey.

Encaustic tile and ornamental pottery.—Encaustic tile are at present manufactured in only three places in the United States—at Zanesville, Ohio; Indianapolis, Indiana; and Perth Amboy, New Jersey. The Perth Amboy pottery produced in 1883 tile valued at $100,000 on an invested capital of $78,000, and employed 130 persons in the manufacture. The amount produced at Zanesville and Indianapolis is not reported.

There are several potteries at Trenton, New Jersey, which make ornamental pottery. Some of it is highly artistic, and will compare favorably with the work of foreign potteries. The same is true of the ornamental work produced at the George Ward Rockwood pottery of Cincinnati, Ohio. Both molded and turned wares are made here in antique and modern styles; the decoration is overglaze, underglaze, and smearglaze; and vase gilding is also done.

Ornamental pottery of the best grades is now made at Baltimore, from the clays of Howard and Anne Arundel counties, Maryland. The pottery is said to be quite equal to the best made in Trenton or Cincinnati, and several features of the establishment are unique in this country. The temperature obtained in the kilns is much higher than that of the English kilns, and the resulting ware has a fine vitreous body. Much attention has been given to coloring this body, producing many ornamental effects without the use of paint. In the final decoration underglaze, as well as the usual colors, has been used with good effect. A variety of real Parian porcelain has been produced which is new in this country, and has attracted attention both here and in England. The paste is said to be as pure as the finest old Sevres biscuit; it has a characteristic creamy tint, and is very translucent. Some articles of fine tableware have been made from this paste in the form of egg-shell porcelain; it has been chiefly used, however, for ornamental figures in relief. Although this development of ornamental pottery at Baltimore is quite new, its importance can be judged from the fact that 1,000 plaques of one particular style have lately been ordered for the English market in competition with ware from the Wedgwood potteries.

Terra cotta.—New Jersey produces the largest amount of these goods, and next comes Ohio. Considerable is made in Boston, and some at Baltimore and Chicago. In 1883 the three leading works in New Jersey produced common and architectural terra cotta valued at $438,000. The capital invested in these works was $325,000, and 432 persons were employed by them. For 1884 the value of the terra cotta made is estimated at $450,000. A large amount is produced in the clay district on the Ohio river, in Ohio, chiefly the common kinds.

Drain tile.—Illinois produces the largest amount of drain tile made in any one State. Large quantities are also made in Indiana and Ohio. New Jersey produces considerable, and Pennsylvania also is a producing State. It is made wherever the drainage of the surface of the soil is demanded and suitable clay can be found.

The statistics for 1884 of the Illinois drain-tile industry are as follows:

Statistics of the drain-tile industry of Illinois in 1884.

Number of counties in which drain tile was manufactured	75
Number of factories	536
Amount of capital employed	$3,794,000
Number of employés	5,495
Amount paid in wages during the year	$1,434,163
Average number of months in operation	7
Total value of tile made	$3,960,958
Whole number of tile made	176,962,821

The production of Indiana is reported as follows:

Production of drain tile in Indiana.

Years.	Number of establishments.	Capital employed.	Value of product.	Hands employed.
1879	297	$456,489	$623,720	948
1880(*a*)	486	700,000	900,000	2,187
1882	261	491,130	764,345	1,086
1883	387	759,562	1,133,515	1,517

a Estimated; evidently too high.

It is thought that in 1884 there was a general slight increase in the production of drain tile.

Sewer pipe.—In 1880 the State producing the largest amount was Ohio; next came New York, then Missouri, New Jersey, Illinois, Pennsylvania, and Indiana. It is estimated in *B* that the value of the annual product of Ohio is $3,000,000, and that New York produces annually about $1,500,000. In 1883 New Jersey produced pipe valued at $388,000. It is reported in general terms that there was a small increase in the production of sewer pipe in 1884, but definite figures for the several States are not obtainable.

ROCKY MOUNTAIN DIVISION.

The manufacture of clay goods in the Rocky Mountain division is almost wholly confined to Colorado, and the establishments in that State are located at Golden and Denver. They make several grades of firebrick, fine silica-lime brick, pattern brick for furnaces and furnace arches, muffles, crucibles, scorifiers, and other articles for similar uses. All the firebrick used in the various smelting works of Colorado and New Mexico are made either at Golden or Denver, and the quality of the muffles, scorifiers, and crucibles made there is acknowledged to be fully equal, if not superior, to the imported Battersea goods, and they have gradually usurped the place of the latter in the assay offices of this region.

No statistics of the production of firebrick, muffles, etc., are available, and the consumption of fireclay by the works at Denver and Golden could not be ascertained for the years previous to 1880 except in one case. The following table gives the amount of clay used, by years, in tons of 2,000 pounds. Previously to 1880 the Denver Fireclay Company, of Denver, used 1,500 tons of clay in manufactures.

Fireclay used by the Colorado works.

Works.	Location.	1880.	1881.	1882.	1883.	1884.
Cambria Brick and Tile Company	Golden	....	2,000	3,000	3,000	500
G. A. Duncan & Co	do	4,000	6,000	9,000	10,000	12,000
Golden Brick and Coal Company	do	5,000	4,500	960	750	1,200
Denver Fireclay Company	Denver	1,200	1,200	1,500	1,200	3,200
Denver Firebrick Company	do	....	....	4,000	1,600	....
Total		10,200	13,700	18,460	13,850	16,900

The number of firebrick made in 1882 at Golden is estimated at 2,500,000, and the total value of all the products of the industry at the same place at $167,000.

There are two pottery establishments in Colorado: the Columbia Brick and Tile Works at Golden, and the Terra Cotta Works at Denver, owned by Mr. Thomas Moulton. These works manufacture drain tiles, of the best quality, pavement tiles, and large quantities of sewer pipe. Both works also make flower pots, hanging baskets, jars, jugs, and many other forms of earthenware. The entire local market and the demand in the adjoining towns is supplied from their products.

Firebrick and crucibles are made at Helena, Montana, from a clay found near by, to supply the local demand of the smelting and roasting furnaces of Helena and Butte, but no statistics of the amount of wares produced here were obtained.

PACIFIC COAST.

Mr. Yale reports as follows for California: "Although clays, of varying excellence, are widely and plentifully distributed, there are not over a dozen potteries being operated in the State, the products of which are mainly of the coarser sorts of crockery, such as stone jars, jugs, and crocks, flower pots, and vases; ironstone, sewerage and drainage pipes; fire and subirrigation tiles, stove and flue linings, well tubing, water filters and coolers; acid receivers and chemists' and assayers' utensils; firebrick, terra cotta, etc. Tableware or other better descriptions have not yet been manufactured. These establishments employ a total of 300 hands, one-fourth of the number being Chinese—these people being engaged only by the larger companies. The capital invested in this business amounts to $400,000; aggregate yearly value of products $375,000; money expended for wages $130,000, the Chinese being paid $1 and white laborers from $1.75 to $2.50 per day. Where employés board and lodge themselves, as the Chinese usually do, there is, of course, some difference in the rates. In the coast counties the potteries are operated without intermission the year round. Those situated further in the interior suspend work during the winter, with the exception of the larger establishments, where most operations are then carried on within doors. The long dry seasons of California greatly favor the prosecution of this business, enabling the potter to very effectually dry his wares and perform much of his work in the open air.

"But, notwithstanding these natural advantages, coupled with an ample supply of the raw material, this industry has undergone but little expansion in California, partly because the manufacturer has had only a limited market for his wares, but chiefly because of the competition to which he has been subjected through free and often excessive foreign importation, it having been the practice of ships visiting the port of San Francisco to load with wheat, to bring everything in this line, firebrick included, at very low freights—sometimes as ballast. The effect of this cheap transportation has been to keep the market overstocked and prices depressed, so that a more rapid growth of this home industry was impossible. Then, too, there having been for a time, at first, but little demand for ornamental and architectural pottery, the California manufacturer confined his efforts to the making of the cheaper and commoner wares, those involving elegance of design and artistic skill having been neglected. Now, these, after having come to be in large request, insure for the business better returns and a more rapid development.

"*Firebrick.*—The manufacture of firebrick still remains among the large class of possible but as yet undeveloped industries of California. There are suitable clays, the skill to manipulate them, and a considerable local consumption, but these advantages have not availed to supply the home demand to any great extent, having been neutralized by the cheapness of the imported article, now selling in San Francisco—the principal distributing point for the Pacific coast—at about $40 per thousand, a price at which they can hardly be made in any part of California. As a general thing, the English firebrick have been preferred to those made in California, and generally for the reason that too little care has been observed in selecting the clay or in manufacturing the brick.

"*Common brick.*—Of building brick, about 245,000,000 are burnt annually in California, their use, as compared with the population, being rather limited. Formerly when the business portions of the cities and the larger towns were being built up, a great many brick were called for. But now the buildings being put up without the fire limits of the towns are nearly all constructed of wood, which, besides being cheaper, is better adapted to the climate than either brick or stone; hence the comparatively limited use of these latter for building purposes in California. A tolerably good clay for making brick is found in many parts of the State, notably on the bay shore of Marin and Contra Costa counties. From a bed of this material near San José, in Santa Clara county, a pressed brick is made, claimed to be equal to the best imported. During the wet season, extending usually from about the middle of November to the end of April, the business of brick making is suspended in the State except where the burning is conducted in large furnaces by the Hoffman process, which admits of its being prosecuted constantly. The average price of common brick in San Francisco is $9 per 1,000; delivered at the kilns from 15 to 20 per cent. less; pressed brick sell at about $27 per 1,000. There is probably $1,000,000 invested in the brick business in California, which calls for the service of about 1,600 men during the dry, and one-third as many during the wet season, 36 per cent. of the whole being Chinamen. Wages $70 per month for burners; $45 for molders and setters; and $37 for ordinary hands—board being always included; for Chinese, less these rates by 40 per cent."

A considerable number of common brick enter the port of San Francisco from England. The imports during 1884 were large, falling but little below those of 1883.

Imports of brick at San Francisco.

Years.	Number of brick.
1880	730, 040
1881	1, 608, 256
1882	1, 647, 883
1883	1, 984, 772
1884	1, 929, 352

A large number of firebrick were also imported from England during 1884.

GENERAL STATISTICS.

The following figures, chiefly taken from the census of 1880, are given to partially show the condition of the various industries connected with the clay deposits of the United States in that year:

In regard to earthenware, whiteware, and stoneware Ohio had 179 establishments, with a capital of $1,675,055, employing 2,659 hands and producing goods valued at $2,106,474. New Jersey had 49 establishments, with $2,057,200 capital, 3,130 employés, and produced wares to the value of $2,598,757. New York had a capital of $703,500 invested in this branch of production; Pennsylvania, $670,545; Massachusetts, $187,000; Illinois, $168,000; Maryland, $142,000; and no other State or Territory reached $100,000.

In the brick and tile industries Ohio had $2,723,528 invested, and there were in the State 825 establishments; Pennsylvania had 521 establishments, with a capital of $5,028,524; New York, 321, with a capital of $3,923,405; Indiana, 735, with a capital of $1,084,264; Illinois, 616, with a capital of $2,397,023; Iowa, 280 establishments, with $478,614 invested in them; Missouri, 230, and $989,415 capital; Wisconsin, 119 works, with $560,870 capital; Kentucky, 115, with $302,175 invested; Massachusetts, 114 establishments, with $1,688,200 invested, and New Jersey, 107, with $1,731,200 invested. Texas had 113 works; but the capital in them was only $183,500, and no other State had 100 establishments.

The number of hands employed in these same industries was as follows: Pennsylvania, 8,426; New York, 7,363; Ohio, 6,127; Illinois, 5,903; Indiana, 4,239; New Jersey, 2,749; Missouri, 2,737; Massachusetts, 2,401; Iowa, 2,251; Michigan, 1,933; Tennessee, 1,553; Virginia, 1,425; Wisconsin, 1,395; Kentucky, 1,379; Georgia, 1,228; Texas, 1,185; Kansas, 1,046; and Minnesota, 1,010.

Or, summing up, there were in the census year 686 establishments producing pottery, as defined in our list; they had invested in them

$6,380,610, employed 8,494 hands, paid in wages during the year $3,279,535, used raw material to the value of $2,564,359, and the value of their products was $7,942,729.

There were also 5,631 establishments making brick, drain tile, tile, etc.; the capital invested in them was $27,673,616; the number of hands employed, 66,355; wages paid, $13,443,532; material used (including fuel), worth $9,774,834; made 3,822,362,000 common brick, 163,184,000 firebrick, 210,815,000 pressed brick, $2,944,239 worth of tile, $1,765,428 worth of drain tile, $719,926 worth of all other articles, and produced wares having a total value of $32,833,587.

No attempt at a complete canvass of the production in recent years has been attempted. On the basis of the census figures, however, in connection with the known changes in building activity and in price, it is estimated that the total value of the brick and tile made in the United States in 1882 was $34,000,000; in 1883 the production was undoubtedly larger, but was offset by the decline in prices, the total probably being about the same ($34,000,000); in 1884 manufacturers cut down expenses still further, and while about the same number of brick and tile were made as in 1883, the total value probably did not exceed $30,000,000.

IMPORTS AND EXPORTS.

Large as are the amounts of wares manufactured from clay in the United States the demand is not satisfied by them, and the yearly imports are extensive. There is a small export trade, but the imports far exceed the exports in amount and value, as will appear from the following tables. Many articles mentioned in the preceding pages are not imported, home supply equaling the demand for them, and therefore the tables cover by far the larger portion of the value of imports of clay products.

Clay imported and entered for consumption in the United States, 1867 *to* 1883 *inclusive.*

Fiscal years ending June 30—	Fuller's earth.		Kaolin.		Unwrought pipeclay and fireclay.		Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	Long tons.		*Long tons.*		*Long tons.*		
1867	280.25	$3,113	....	....	6,383.75	$72,204	$75,317
1868	211.00	2,522	....	....	8,384.75	66,958	69,480
1869	324.10	3,587	....	....	12,963.75	84,645	88,232
1870	239.40	2,619	....	....	8,014.15	76,057	78,676
1871	290.20	3,383	....	....	10,900.48	103,144	106,527
1872	274.00	3,358	....	....	13,081.20	128,130	131.488
1873	251.18	2,978	1,378.30	$13,091	12,883.82	141,927	157,996
1874	277.20	3,440	89.21	1,378	12,909.14	147,782	152,600
1875	300.06	3,694	130.47	1,977	10,374.65	116,307	121,978
1876	246.73	3,097	142.00	2,152	11,799.12	126,738	131.987
1877	400.00	4,460	204.26	3,009	11,680.14	129,016	136,485
1878	335.07	4,095	3,499.30	38,899	9,406.74	95,877	138,861
1879	361.21	4,269	4,774.60	45,272	8,477.80	87,948	137,489
1880	578.00	6,925	7,823.66	67,740	11,899,80	117,350	192,015
1881	267.55	3,207	6,887.37	66,654	12,444.28	123,545	193,406
1882	908.27	11,444	13,954.85	135,448	12,181.39	119,620	266,512
1883	1,241,27	14,309	12,870.60	115,492	7,841.32	74,673	204,474

In 1884 the imports were classified as follows:

Kinds.	Long tons.	Value.
China clay or kaolin	16, 112	$131, 063
All other:		
Unwrought	11, 021	85, 990
Wrought	2, 149	16, 158
Total	29, 282	233, 211

Building brick imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
1868		$44, 453	1877	129, 970	$897
1869		59, 359	1878	25, 170	166
1870		46, 892	1879	918, 840	4, 534
1871		52, 997	1880	349, 000	1, 662
1872		5, 275	1881	539, 600	3, 002
1873	963, 500	6, 982	1882	711, 150	9, 168
1874	594, 330	4, 929	1883	764, 700	7, 958
1875	495, 500	3, 278	1884 (*a*)	531, 820	9, 985
1876	411, 550	3, 147			

a Classed as "brick other than firebrick."

Bathbrick and firebrick imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1868	$8, 763	1877	$43, 548
1869	86	1878	36, 679
1870	19, 112	1879	44, 681
1871	18, 215	1880	60, 589
1872	47, 502	1881	82, 581
1873	60, 442	1882	69, 575
1874	66, 428	1883	124, 948
1875	50, 325	1884	*b* 103, 309
1876	69, 063		

b Firebrick only.

The number of firebrick imported was as follows, since 1877:

Fiscal years ending June 30—	Imports.	Fiscal years ending June 30—	Imports.
	Number.		*Number.*
1877	303, 870	1881	1, 968, 230
1878	244, 614	1882	2, 831, 033
1879	690, 954	1883	1, 250, 135
1880	1, 504, 462	1884	1, 524, 000

Earthenware and china imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Brown earthen and common stoneware.	China and porcelain not decorated.	China and porcelain decorated.	Other earthenstone or crockery, glazed, etc.	Total.
1867	$48, 618	$418, 493	$439, 824	$4, 280, 924	$5, 187, 859
1868	47, 208	309, 960	403, 555	3, 244, 989	4, 005, 712
1869	34, 260	400, 894	555, 425	3, 468, 970	4, 459, 549
1870	47, 457	420, 442	530, 805	3, 461, 524	4, 460, 228
1871	96, 695	391, 374	571, 032	3, 573, 254	4, 632, 355
1872	127, 346	470, 749	814, 134	3, 896, 664	5, 308, 893
1873	115, 253	479, 617	867, 206	4, 289, 868	5, 751, 944
1874	70, 544	397, 730	676, 656	3, 686, 794	4, 831, 724
1875	68, 501	436, 883	654, 965	3, 280, 867	4, 441, 216
1876	36, 744	409, 539	718, 156	2, 948, 517	4, 112, 956
1877	30, 403	326, 956	668, 514	2, 746, 186	3, 772, 059
1878	18, 714	289, 133	657, 485	3, 031, 393	3, 996, 725
1879	19, 868	296, 591	813, 850	2, 914, 567	4, 044, 876
1880	31, 504	334, 371	1, 188, 847	3, 945, 666	5, 500, 388
1881	27, 586	321, 259	1, 621, 112	4, 413, 369	6, 383, 326
1882	36, 023	316, 811	2, 075, 708	4, 438, 237	6, 866, 779
1883	43, 864	368, 943	2, 587, 545	5, 685, 709	8, 686, 061
1884	50, 172	982, 499	2, 664, 231	666, 595	4, 363, 497

Value of tiles imported for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Encaustic.	Roofing and paving.	Total.
1868	$11, 423	....	$11, 423
1869	7, 599	$1, 443	9, 042
1870	8, 549	875	9, 424
1871	4, 771	884	5, 655
1872	8, 083	31, 453	39, 536
1873	18, 717	51, 772	70, 489
1874	14, 193	51, 010	65, 204
1875	15, 401	45, 360	60, 761
1876	15, 267	29, 903	45, 170
1877	16, 787	42, 143	58, 930
1878	13, 112	41, 032	54 144
1879	17, 355	31, 177	48, 532
1880	16, 896	34, 063	50, 959
1881	21, 106	43, 717	64, 823
1882	27, 729	46, 562	74, 291
1883	16, 459	83, 777	100, 236
1884	16, 011	115, 770	131, 781

Value of clay exported from the United States, 1865 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1865	$20, 975	1877	$5, 493
1869	5, 065	1878	8, 384
1870	2, 354	1879	6, 314
1871	10, 904	1880	8, 355
1872	5, 275	1881	8, 762
1873	4, 970	1882	17, 458
1874	8, 146	1883	17, 790
1875	13, 933	1884	7, 725
1876	4, 325		

Value of brick, etc., of domestic production exported from the United States.

Fiscal years ending September 30, until 1842, and June 30 since.	Brick and lime.	Brick, lime, and cement.	Firebrick and firetile.	Brick, other than fire.	Total.
1826	$6, 075				$6, 075
1827	3, 365				3, 365
1828	4, 573				4, 573
1829	3, 717				3, 717
1830	2, 482				2, 482
1831	4, 412				4, 412
1832	3, 502				3, 502
1833	3, 866				3, 866
1834	4, 294				4, 294
1835	4, 133				4, 133
1836	6, 829				6, 829
1837	29, 626				29, 626
1838	31, 322				31, 322
1839	16, 298				16, 298
1840	16, 949				16, 949
1841	14, 064				14, 064
1842	5, 728				5, 728
1843 (nine months)	3, 883				3, 883
1844	12, 833				12, 833
1845	8, 701				8, 701
1846	12, 578				12, 578
1847	17, 623				17, 623
1848	24, 174				24, 174
1849	8, 671				8, 671
1850	16, 348				16, 348
1851	22, 045				22, 045
1852	13, 539				13, 539
1853	32, 625				32, 625
1854	33, 194				33, 194
1855		$57, 393			57, 393
1856		64, 297			64, 297
1857		68, 002			68, 002
1858		103, 821			103, 821
1859		160, 611			160, 611
1860		154, 045			154, 045
1861		93, 292			93, 292
1862		83, 385			83, 385
1863		99, 313			99, 313
1864		49, 106			49, 106
1865		64, 105			64, 105
1866		146, 874			146, 874
1867		102, 324			102, 324
1868		140, 338			140, 338
1869		83, 229			83, 229
1870			$4, 483	$25, 091	29, 574
1871			18, 471	9, 279	27, 750
1872			10, 233	14, 305	24, 538
1873			14, 651	10, 632	25, 283
1874			22, 365	11, 290	33, 655
1875			14, 476	12, 120	26, 596
1876			20, 348	18, 035	38, 383
1877			9, 892	25, 571	35, 463
1878			13, 900	254, 446	268, 346
1879			11, 096	51, 714	62, 810
1880			12, 027	36, 299	48, 326
1881			12, 290	27, 989	40, 279
1882			30, 649	50, 870	81, 519
1883			47, 120	56, 227	103, 347
1884			41, 012	60, 702	101, 714

During the years given there were exported from the port of New York the following number of building brick and firebrick:

Building brick and firebrick exported from New York.

Calendar years.	Building brick.		Firebrick.	
	Number.	Value.	Number.	Value.
1877	13,603,475	$70,629	45,000	$2,185
1878	4,471,980	29,457	118,994	3,148
1879	1,381,775	9,371	94,976	6,867
1880	921,654	7,486	80,000	3,208
1881	971,500	8,663	181,359	8,361
1882	778,000	7,026	269,810	9,843
1883	2,642,625	21,737	358,616	11,039
1884	1,702,850	14,148	300,100	9,042

Value of earthenware and stoneware of domestic manufacture exported from the United States.

Fiscal years ending September 30, until 1842, and June 30, since.	Value.	Fiscal years ending September 30, until 1842, and June 30, since.	Value.	Fiscal years ending September 30, until 1842, and June 30, since.	Value.
1790	$1,990	1845	$7,393	1866	$31,616
1791	1,984	1846	6,521	1867	29,308
1826	1,958	1847	4,758	1868	29,528
1827	6,492	1848	8,512	1869	19,213
1828	5,595	1849	10,632	1870	42,120
1829	5,592	1850	15,644	1871	37,383
1830	2,773	1851	23,096	1872	48,941
1831	7,378	1852	18,310	1873	53,909
1832	6,333	1853	53,685	1874	59,494
1833	12,159	1854	33,867	1875	92,253
1834	12,745	1855	32,119	1876	73,846
1835	16,427	1856	66,696	1877	87,355
1836	13,391	1857	34,256	1878	98,035
1837	14,249	1858	36,783	1879	80,898
1838	12,019	1859	47,261	1880	106,724
1839	11,645	1860	65,086	1881	123,177
1840	10,959	1861	40,524	1882	180,773
1841	6,737	1862	32,108	1883	227,547
1842	7,618	1863	88,244	1884	236,247
1843 (nine months)	2,907	1864	67,591		
1844	4,884	1865	93,258		

NEW YORK MARKET REVIEW.

A complete review of the condition of the markets and amount of trade done in all the articles mentioned in the preceding pages for the entire country during 1884 cannot be given here. Reports in regard to all of them are not obtainable, and if they could be had their insertion would make this report too bulky for its present purpose. A brief review of the markets and trade movements at New York during 1884 for a few of these articles may, however, be of interest to the reader. It may throw some light on the business condition for the year of a few of the important industries connected with our clay deposits. The statistics are derived from the *Real Estate Record and Guide.*

Common brick.—The production of common brick during 1884 in the Hudson River district was about up to the average, but prices ruled lower than during 1883 and remained quite uniform during the season. More brick from the yards in New Jersey came into the New York market than in previous years.

The following was the production of common brick at the points from which New York draws its supply, during the years named:

Production of common brick in the New York district.

Years.	Number.	Years.	Number.
1874	400,000,000	1880	450,000,000
1875	450,000,000	1881	500,000,000
1876	275,000,000	1882	600,000,000
1877	300,000,000	1883	650,000,000
1878	350,000,000	1884	600,000,000
1879	350,000,000		

Stock of brick on hand at base of supplies for New York, January 1.

Localities.	1883.	1884.	1885.
Haverstraw bay, etc	66,000,000	70,000,000	96,000,000
Other points on Hudson river	25,000,000	30,000,000	92,000,000
New Jersey	10,000,000	12,000,000	27,000,000
Long Island	8,000,000	8,000,000	6,000,000
Staten Island	3,000,000	2,500,000	3,000,000
Total	112,000,000	122,500,000	224,000,000

More front building brick were manufactured than in 1883, and the demand was good during the early part of the season, but much poorer later, leaving manufacturers with larger stocks than usual to carry over. Below are given comparative prices for common and front building brick on January 1 for the seasons of 1883, 1884, 1885:

Prices of building brick in the New York market, per thousand.

Kinds.	1883.	1884.	1885.
Pale brick	$4 75 to $5 00	$3 50 to $4 00	$2 50 to $3 25
New Jersey brick	8 50 8 75	6 00 6 50	4 50 5 50
Hudson River brick	8 50 9 25	6 75 7 75	5 00 6 25
Croton front brick	12 00 15 00	13 00 15 00	13 00 15 00
Philadelphia front brick	30 00	27 00	22 50 23 00
Baltimore front brick	38 00 40 00	37 00 38 00	37 00 40 00

The export trade in common and pressed brick has been chiefly to the West Indies.

There has been a good and growing trade in hollow brick for fireproofing purposes during the year, and there is promise of still further increase. Prices have ranged from $11 to $14 per thousand, according to make, etc., but $12 was about the average for the regular sizes, while "shapes" were mainly sold on contract per square foot.

Firebrick.—In firebrick the trade was unsatisfactory and slow. Less business was done than during 1883, and manufacturers do not look hopefully on the prospects for the coming year. The stagnation in the iron industry has been an important factor in this condition of affairs, but a more important one is found in the competition with foreign products. Much foreign stock has been imported in ballast or at merely nominal freights, so that although the American brick were as good or even better than foreign makes, the American makers could not market their stock at advantageous prices. Ruling prices on January 1, 1884 and 1885, are given below.

Prices of firebrick in the New York market, per thousand.

Kinds.	1884.		1885.	
Welsh	$30 00 to	$35 00	$25 00 to	$30 00
English	25 00	30 00	25 00	30 00
American, No. 1	33 00	35 00	30 00	35 00
American, No. 2	25 00	30 00	25 00	30 00

ABRASIVE MATERIALS.

BUHRSTONES.

Nearly all the buhrstones used in this country are imported. They come mainly from France, the principal locality of production there being the Paris basin. They are also imported in smaller amounts from Belgium and Germany. The French and Belgium stones consist of silica mixed with calcareous material, and are both hard and porous. The German stones are said to be of basaltic lava. These stones are imported in the rough, at low rates of freight, and are finished in this country.

Stones answering some of the purposes of buhrstones are found in various parts of the United States and are quarried and worked to some extent. The leading localities in which these stones are found are as follows: Ulster county, New York—the stone, which is known as Esopus stone, is a quartzite of variable texture and hardness; Lancaster county, Pennsylvania—this stone, which is known to the trade as the Cocalico, is a conglomerate, and is found in the form of bowlders scattered over the surface; Peninsula, Ohio, where a white variety of the Berea Grit is worked, mainly for the purpose of grinding oatmeal and barley. In addition to the above localities, stones more or less suitable for coarse work are, or have been, quarried in parts of Virginia, North Carolina, Georgia, Alabama, Missouri, and Arkansas. They are also reported to exist in Owen's Lake valley, and in the Pitt River country, in California.

The American stones are not used at all for grinding wheat, but only for the coarser cereals, and for grinding paints, cement, chemicals, fertilizers, charcoal, etc. The imported stones, being finer in grain and much harder, are used for grinding wheat and for all the better class of work. The use of rollers, as a substitute for buhrstones, is gaining ground with great rapidity. Indeed, at present, nearly all the large flouring mills in the country are adopting the roller system, and there is every probability that for many other purposes buhrstones will be replaced by rollers or other grinding machinery in the near future.

The estimates of production of American buhrstones range through wide limits, from a merely nominal value up to $350,000. In all probability, $300,000 is an approximation to the correct value.

The following table presents the value of the imports of buhrstone in each fiscal year since 1868:

Buhrstones and millstones imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Rough.	Made into millstones.	Total.	Fiscal years ending June 30—	Rough.	Made into millstones.	Total.
1868	$74, 224	....	$74, 224	1877	$60, 857	$23, 068	$83, 925
1869	57, 942	$2, 419	60, 361	1878	87, 679	1, 928	89, 607
1870	58, 601	2, 297	60, 898	1879	101, 484	5, 088	106, 572
1871	35, 406	3, 698	39, 104	1880	120, 441	4, 631	125, 072
1872	69, 062	5, 967	75, 029	1881	100, 417	3, 495	103, 912
1873	60, 463	8, 115	68, 578	1882	103, 287	747	104, 034
1874	36, 540	43, 170	79, 710	1883	73, 413	272	73, 685
1875	48, 068	66, 991	115, 059	1884	45, 837	263	46, 100
1876	37, 759	46, 328	84, 087				

The decrease of imports in the last two years is doubtless owing to the increase in the use of rollers.

GRINDSTONES.

The principal source of grindstones in the United States is the geological formation known as the Berea Grit, which underlies large areas in the northeastern part of Ohio. It is a fine-grained sandstone, but differs greatly in texture and hardness in different localities. It is quarried for this purpose mainly at Berea, Amherst, Independence, Massillon, Lorain, Grafton and Marietta, and the principal locality for the manufacture of the stones is Cleveland, Ohio. The Berea stone has a white color, a fine and sharp grit, and is used generally for sharpening edge tools. The Amherst stone is brownish white in color, with a soft, loose grit, and is used to sharpen edge tools and saws. That from Independence has a grayish white color and a coarse sharp grit. It is used for grinding springs and files and for dry grinding of castings. The Massillon stone is yellowish in color, with a grit very similar to the last, and is used for similar purposes. Near Grindstone City, Michigan, there is found a fine-grained argillaceous stone, of a uniform blue color, which is in general use for finishing work, especially where a very fine edge is required. The production during the year 1883 is estimated to have had a value of about $600,000. In 1884 the production was not quite as great, being estimated at $570,000.

The exports of grindstones are small in amount and are mainly to the West Indies, Mexico, and Central and South America. The imports are also small in value, and are derived mainly from Nova Scotia, England, Scotland, France, and Belgium. The amount and value of the imports since 1868 are given in the following table. Amounts are given in long tons of 2,240 pounds.

Grindstones imported and entered for consumption in the United States, 1868 to 1883 inclusive.

Fiscal years ending June 30—	Finished.		Unfinished or rough.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Long tons.		*Long tons.*		
1868	....	$25,640	....	$35,215	$60,855
1869	....	15,878	....	99,715	115,593
1870	....	29,161	....	96,444	115,605
1871	385	43,781	3,957.15	60,935	104,716
1872	1,202	13,453	10,774.80	100,494	113,947
1873	1,437	17,033	8,376.81	94,900	111,933
1874	1,443	18,485	7,721.44	87,525	106,010
1875	1,373	17,642	7,656.17	90,172	107,814
1876	1,681	20,262	6,079.34	69,927	90,189
1877	1,245	18,546	4,979.75	58,575	77,121
1878	1,463	21,688	3,669.41	46,441	68,129
1879	1,603	24,904	4,584.16	52,343	77,247
1880	1,573	24,375	4,578.59	51,899	76,274
1881	2,064	30,288	5,044.71	56,840	87,128
1882	1,705	30,286	5,945.61	66,939	97,225
1883	1,755	28,055	6,945.63	77,797	105,852

In 1884 the total imports, finished and rough, were 7,056 tons, valued at $86,286.

CORUNDUM AND EMERY.

BY T. M. CHATARD.

Properties.—Alumina (the oxide of aluminum) is often found native, and is then known as corundum. In its purest state it is transparent and colorless, but is usually tinted by traces of oxides of other metals, forming gems known, according to the color, as sapphire, oriental emerald, oriental ruby, or oriental topaz, the term "oriental" being prefixed to distinguish these precious stones from others of the same name but of different composition, and a less degree both of hardness and brilliancy. So far, although the localities of the mineral are numerous and the amount discovered is large, but little corundum available for gems has been found in the United States; while, on the other hand, a large and increasing demand for the coarser non-transparent material has arisen through its application as an abrading agent. The corundum gem stones are described on page 733 *et seq.* of this report.

Mechanically mixed with varying proportions of oxide of iron corundum forms the well-known emery, or, as it is usually called, Turkey emery. This is found in large quantities in Asia Minor, near Smyrna and Ephesus, and also in the island of Naxos and other islands of the Grecian archipelago. It owes its value as a grinding and polishing agent to the corundum contained in it.

Next to the diamond, corundum is the hardest of all known substances, especially in its gem form. If sapphire be taken as 100, corundum from North Carolina has an abrasive power represented by from

90 to 97; while the best Naxos emery ranges from 40 to 57, or about one-half that of corundum, a difference which must be taken into consideration in every stage of the preparation and use of the materials.

American occurrences.—Emery has not been found in any quantity within the limits of the United States, while corundum occurs in a very large number of localities among the older rocks of the Atlantic States, ranging from Massachusetts to Alabama. The Turkey emery is found in granular limestone overlying gneissoid rocks, and in the corresponding limestones of this country some little corundum has been found; but so far (unless the locality of Chester, Massachusetts, be considered an exception) it is only in connection with the chromiferous serpentine or chrysolite formation that any large bodies of the mineral have been discovered.

Although this serpentine formation has a considerable development in Pennsylvania and adjacent States, and corundum has been found in many places along its course, the yield has been small in comparison with the more southern localities of North Carolina and Georgia. Throughout a belt of country stretching from Dudleyville, Alabama, through Georgia, the western portion of South Carolina and North Carolina to the Virginia line, and about 100 miles in width at its greatest extension, corundum is found, and, although many of the localities have furnished only surface specimens and no such excavations have been made as would discover the mineral in place or show the nature of the accompanying rocks, it is reasonable to suppose, in view of what has been already done, that throughout this region the corundum occurs in close connection with chrysolitic rocks. More than fifty localities are already known and new ones are continually being added. (See lists, "Mineral Resources of the United States, 1882," page 667 *et seq.*)

It is at Corundum hill, Macon county, North Carolina, and at Laurel creek, Georgia, 26 miles southeast of the former, that the most extensive work has been done and the best opportunity is offered for the study of the nature of the occurrence. These two mines are owned and worked by the Hampden Emery Company of Chester, Massachusetts, the pioneer of American corundum mining and the largest operator in it. Under the management of Dr. H. S. Lucas this company began operations at the Chester locality and has built up a large and profitable trade, the increasing demands of which have necessitated new sources of supply, which have been found in the South. Taking hold of Corundum hill, then practically abandoned as useless, it has within the past six years created a flourishing business, the output of the two mines being ample for present wants. So far the preparation of the corundum at the mines has been confined to concentrating the mineral so as to allow of its economical shipment to the mill at Chester, Massachusetts, where the final cleaning and sizing is effected; but a large mill is now being built at Corundum hill, to allow of the turning out of a finished product.

At Corundum hill there is a large outcrop of chrysolitic rock, or dunyte, lying in and intermixed with hornblende-gneiss, both the chrysolite and adjacent gneiss being much decomposed. The chrysolite appears to have been fractured in every direction, and along the lines of these fractures decomposition has been most rapid, giving a spheroidal appearance to the masses of the rock. The gneiss as it appears amongst the chrysolite has a northeast and southwest strike, dips almost perpendicularly, presenting a coarse, loosely compacted appearance, and retaining the structure of the original rock. The corundum is found in chlorite (*a*) lying between the chrysolite and the gneiss, separated from them by bands of talcose and chloritic material, which are much thicker on the side of the chrysolite, where a succession of subfibrous and micaceous minerals, such as talc, enstatite, steatite, and other magnesian substances, frequently interlaid with chalcedony and often so decomposed as to form clays, leads to a kernel of more or less altered chrysolite. As the result of this alteration one often finds large globular masses of apparently solid rock, which prove on examination to consist of a tough casing of talcose rock surrounding and inclosing a mass of soft, wet, clay-like material, generally having in the center some harder but altered chrysolite. In most parts of the mine the corundum is found in crystalline masses, often of considerable size, one crystal having been found weighing 375 pounds; and at times specimens occur which are sufficiently transparent and tinted to be of value as gems. At present, however, the principal part of the product is obtained from the so-called "sand vein" which lies on the easterly side of the formation. This is a vein of chloritic material, consisting of small scales of a reddish and yellowish brown color, containing small crystals and grains of corundum scattered in profusion through it. The material is soft enough to be worked by a stream of water delivered through a hose and pipe. The water not only excavates the corundum, but also washes it and conveys it to the mill, where it is subjected to further washing and cleaning. The vein is in places 6 to 8 feet wide and is very cheaply mined, the corundum being of excellent quality and, owing to the granular condition, far advanced in preparation.

At Laurel creek the corundum lies between the gneiss and chrysolite, in a band of steatite, chlorite, and talc, the latter generally indurated. The spheroidal condition of the chrysolite is not so well marked as at Corundum hill, and the succession of the alteration products is somewhat different, but there can be no doubt that the same agencies have been at work in substantially the same manner. The corundum occurs on the south side of a hill of chrysolite, which gradually changes

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[a] The names given to the different minerals are only approximations and generally such as are used by the miners; thus under "chlorite" is understood a large series of hydrous micaceous minerals of greenish, yellowish, or brownish colors. The same may be said of "talc," "serpentine," etc., as representing classes; while "vein" is used to mean any material filling a crevice, except "drift."

into steatite and indurated talc as it approaches corundum. Next comes a vein of chlorite containing the so-called "block corundum," or masses of almost solid corundum sparingly mixed with brown or green chlorite and frequently of great size, several having been obtained of at least 5,000 pounds in weight. The "block corundum" is succeeded by a so-called "horse" of soapstone, and this by a "sand vein" more compact than that at Corundum hill, the chloritic material often breaking out in large masses which are very difficult to disintegrate. Talc, enstatite, and other minerals follow, and finally the gneiss is reached, the whole series having a general east-and-west course and the aggregate width being not less than 100 feet. The whole corundum-bearing formation may be viewed as a counterpart of the so-called "veins" of Corundum hill, though on a much larger scale and not so easily traced.

Both of these mines are well opened and thus can be studied; but while there are many other localities, some showing very good prospects for corundum, few of them have been sufficiently developed either to determine their value or to show the mode of occurrence. In this direction there is a good field for profitable operations, if it be borne in mind that the discovery and proper mining of the mineral are only a portion of the problem. The preparation for market is equally important, and any neglect in this will surely prove most disadvantageous. A good article of well-prepared corundum will sell for double that of emery of the same "number;" and although the latter is much reduced in price, rough ore of good quality being worth at present about $25 per ton at the ports of shipment, at existing prices a good mine well managed should pay very satisfactory profits.

Prospecting for corundum.—In prospecting for corundum the surface indications are to be followed as in searching for other ores, and pits are to be sunk as usual, remembering that corundum is to be looked for neither in the gneiss nor in the chrysolite, but along the contacts of the two rocks, and particularly where the rocks are most altered; if a contact is found it should be carefully followed and the adjacent rocks closely examined. Chlorite, the almost unfailing companion of corundum, is considered a good sign.

In making such a search, particularly in sinking pits, care must be taken that the later sediment or "wash" be not mistaken for original rock in place, an error not infrequently made when the rocks are very much decomposed. The decomposition of the gneiss usually gives a grayish or brownish sandy micaceous product; while the chrysolite, in addition to the talc, steatite, and chalcedony, yields various red and yellow clays often intermixed with small fibers and needles of other minerals, so that the color and appearance of the soil may often give a clue. As the rocks of the southern corundum field are often decomposed to a depth of from 30 to 40 feet, prospecting is sometimes difficult; but a careful preliminary examination of the surface will often save much useless digging, and a single pit located with judgment, and closely observed during the sinking, will generally give more valuable information than a dozen dug at hap-hazard.

From what has been said it will be seen that a corundum mine is necessarily "pockety;" but, if what has been so far observed be generally applicable, there should be no great difficulty in tracing out and finding the various pockets, and if a proper amount of prospecting work be done and the abrasive value of the corundum discovered prove to be satisfactory, before any large investment is made, there is no reason why the same skill and energy necessary in other mining operations should not in this field meet with adequate reward.

Manufacture.—The preparation of corundum and emery has for its object the granulation of the material into a series of "numbers" or grades of fineness, ranging from the finest "flour" up to particles of comparatively large size. All gangue and other extraneous matter must be removed, as it is absolutely necessary, especially in the case of corundum, that all the grains of a given "number" shall be practically of the same size, of equal hardness, and of suitable form. To this end successive crushings alternate with processes of washing, cleaning, and sifting, the machinery employed being similar to that used in ore concentration and usually very simple in construction, but requiring frequent repair and replacement owing to the hardness of the mineral. Stamps and rolls are used for crushing; great care being taken to produce as little "flour" as possible, it being of much less value than the coarser grades. The crushing of emery is generally much easier than that of corundum, though in this respect great differences often exist between the corundum of different localities, and even in that from different parts of the same mine. This is probably due to the tendency of corundum to alter or weather. The researches of Prof. F. A. Genth and others have shown that it yields readily to the action of mineral solvents, becoming softer and more friable, the alumina uniting with other substances to form various other minerals, and these changes proceed with greater rapidity along certain lines of least resistance which originate in the arrangement of the molecules of mineral, and which are clearly shown by the examination of a piece of solid corundum, particularly of its fracture. Even when the change is very slight and invisible to the eye we may have a material apparently solid and unaltered, which though crushing easily and giving a product of good appearance, not only yields too large a proportion of the comparatively valueless "flour," but even a grain deficient in cutting effect. The value of corundum depends entirely on its abrasive power, and this can be easily determined by taking a piece of plate glass previously weighed, placing on it a weighed portion of the sample to be tested, rubbing the material on the glass and continuing the operation until the glass ceases to lose in weight, the total loss in weight of the glass giving the abrasive power of the sample. If the weighings are accurately made and the same weight of material is taken for each experiment, the relative loss suffered by the glass will prove a sure indication of the relative value of the different samples, and such experiments should always be tried on the corundum of any locality before deciding to commence mining.

Almost all the corundum and a large proportion of the emery of commerce are used for the manufacture of the well-known corundum and emery wheels. These wheels are made according to various processes, some of which are known through patents, while others are secret. In all of these methods the cutting material is mixed with some binding compound or "base," molded into form, and then subjected to treatment intended to give the base the qualities necessary for the uses to which the wheel is to be put.(*a*) The much greater hardness of corundum in comparison with emery requires, to obtain the best results, not only special care in the manufacture of the base, but also in the running of the wheel; and as the rapidity of grinding and consequent economy of work are, other things being equal, proportional to the hardness of the grinding material, it is evident that a properly constructed and properly run corundum wheel will, within the range of its work, be far more effective than one made of emery. Where unsatisfactory comparative results have been obtained, they are generally traceable either to defective manufacture or, as is usually the case, to lack of experience in the proper handling of a tool the value of which is amply shown by the steady and increasing demand.

Exports and imports.—The exports of manufactured emery goods, so far as reported, amounted to only $1,857 in the fiscal year 1883, and $3,565 in 1884. Imports of unmanufactured emery during recent years have been as follows:

Emery imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Grains.		Ore or rock.		Pulverized or ground.		Powdered.	Total.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
	Pounds.		*Tons.*		*Pounds.*			
1867	....	....	428	$14, 373	924, 431	$38, 131	....	$52, 504
1868	....	....	85	4, 531	834, 286	33, 549	....	38, 080
1869	....	....	964	35, 205	924, 161	42, 711	....	77, 916
1870	....	....	742	25, 335	644, 080	29, 531	....	54, 866
1871	....	....	615	15, 870	613, 624	28, 941	....	44, 811
1872	....	....	1, 641	41, 321	804, 977	36, 103	....	77, 424
1873	610, 117	$29, 706	755	26, 065	343, 828	15, 041	107	70, 919
1874	331, 580	16, 216	1, 281	43, 886	69, 890	2, 167	97	62, 366
1875	487, 725	23, 345	961	31, 972	85, 853	2, 990	20	58, 327
1876	385, 246	18, 999	1, 395	40, 027	77, 382	2, 533	94	61, 653
1877	343, 697	16, 615	852	21, 964	96, 351	3, 603	....	42, 182
1878	334, 291	16, 359	1, 475	38, 454	65, 068	1, 754	34	56, 601
1879	496, 633	24, 456	2, 478	58, 065	133, 556	4, 985	....	87, 506
1880	411, 340	20, 066	3, 400	76, 481	223, 855	9, 202	145	105, 894
1881	454, 790	22, 101	2, 884	67, 781	177, 174	7, 497	53	97, 432
1882	520, 214	25, 314	2, 765	69, 432	117, 008	3, 708	241	98, 695
1883	474, 105	22, 767	2, 447	59, 282	93, 010	3, 172	269	85, 490
1884	143, 267	5, 802	4, 145	121, 719	513, 161	21, 181	(*b*)	....

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a Considerable information of interest in this connection may be found in an article on "Emery Wheels and Emery-wheel Machinery," by W. O. Rooper, in the English journal *Iron*, of October 24, 1884.

b Not specified.

Exports of manufactured emery.

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1878	$1,608	1882	$813
1879	1,265	1883	1,857
1880	1,312	1884	3,565
1881	1,242		

INFUSORIAL EARTH.

Beds of infusorial or diatomaceous earth have been found at a score of places in California and Nevada, some of the deposits being of great extent. Some small quantities of this substance have been utilized in various ways, chiefly by the manufacturers of soap to mechanically increase the detersive power of their product. A little has also been used as a polishing powder, and has been sold under the name of "El Dorado polish," "electro-silicon," etc. The earth used as electro-silicon was mined in Storey county, near Virginia City, Nevada, several years ago, the stock then obtained having been sufficient to meet the demand since 1881. Companies engaged in making dynamite have been in the habit of importing infusorial earth from Germany, alleging that the domestic article is deficient in absorbent qualities, an opinion, perhaps, due to the employment of impure or badly selected samples; at present, however, other substances are supplanting infusorial earth as an absorbent of nitroglycerine. According to Prof. Joseph Le Conte, the bed of Lake Tahoe, in the deeper portions of the water, which the sediment from the shores has not reached, is composed wholly of diatoms, or infusorial shells, forming an ooze on the bottom.

A deposit locally known as "tripoli" is found on the Patuxent river, near Dunkirk, Calvert county, Maryland. This has been prospected to some extent by Mr. L. McK. Griffith and his associates, and small shipments have been forwarded to Baltimore, Philadelphia, and New York. On November 1, 1884, work was begun on a more extended scale, and drying sheds, storehouses, and a pier have been built. The bed at the river bank is about 7 feet thick, of which the lower half is white and the upper stained yellow by foreign matter. The white earth is of higher quality. In a shaft sunk about 50 yards back from the river, the yellow portion of the bed is found to be only 18 inches thick, while the white is between 5 and 6 feet thick. The earth rests upon greensand marl, and is overlaid by about 8 feet of sand, gravel, and clay, which of course have to be removed before mining the earth. Samples are said to show 84 per cent. silica, one specimen running over 90 per cent., with about 8 per cent. lime. The quantity has been estimated at 50,000 tons. The small sales thus far made were at lower rates than the German kieselguhr, which brings in the New York market about

$18 per ton, the Maryland earth selling at about $10 per ton. The industry being a new one, the product is at the outset at a disadvantage; but the owners hope to introduce the earth extensively during the present year.

Mr. J. M. Cabell has made the following analysis of infusorial earth from near Richmond, Virginia, the sample being carefully taken. The sample proved to be almost exclusively composed of distinguishable infusoria. It is white with a tinge of yellow, feels a little harsh; specific gravity of mass coated with varnish, 0.922; the specific gravity of powder, 2.321.

	Per cent.
Silica:	
Dissolved in 1st hour	29.60
Dissolved in 2d hour	4.97
Undissolved	41.29
	75.86
Alumina	9.88
Ferric oxide	2.92
Lime	.29
Magnesia	.69
Potash	.02
Soda	.08
Nitrogenous matter (nitrogen × 6)	.84
Water by H_2SO_4 3.37 " by 100° C. 1.17 (Less N) by ignition 3.83	8.37
	98.95

To ascertain the solubility of the silica as above, the powder was boiled in a 20 per cent. solution of sodium hydrate.

PUMICE STONE.

A deposit of pumice stone near Lake Merced, a few miles from San Francisco, California, is the only occurrence of this substance utilized in the United States. It supplies the local market, but the amount mined is very small, not exceeding 70 tons yearly. The quality of the pumice is said to be equal to that from the Lipari islands. During recent years the imports of pumice stone have been as follows:

Pumice stone imported and entered for consumption in the United States, 1871 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1871	$6,448	1878	$12,343
1872	12,796	1879	12,892
1873	9,264	1880	15,520
1874	22,899	1881	19,052
1875	8,726	1882	29,370
1876	9,122	1883	50,634
1877	11,556	1884	26,667

ROTTENSTONE.

This substance, sometimes known as "tripoli," in the trade, is a decomposed siliceous limestone, the lime of which has been washed away, leaving the silica in condition to be used as an abrading agent. It is not produced in the United States, the supplies being brought mainly from Great Britain. Recent imports have been as follows:

Rottenstone imported and entered for consumption in the United States, 1873 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1873	$3, 494	1879	$3, 330
1874	353	1880	8, 640
1875	1, 900	1881	3, 848
1876	2, 651	1882	8, 301
1877	675	1883	6, 749
1878	1, 396	1884	4, 402

PRECIOUS STONES.

By George F. Kunz.

Introduction.—This paper slightly repeats some of the material of the former one in the 1882 report, but this is scarcely to be avoided. The time allowed for the first paper was scarcely sufficient for consulting the literature to any great extent, and it was prepared from material at hand or from personal observation. The interval of over a year has afforded the time necessary to inquire into and verify the authenticity of this matter. Where the material has been duplicated, it is only in part, and fuller or more authentic facts are added in this report. A number of localities are mentioned where, although no gems have as yet been found, the material at times is very nearly good enough for gems; or else from the small amount of development, the possibility of gems being found in the future may fairly be inferred. A few localities are mentioned where specimens unexampled as such have been found, and have a claim on the gem collector, since they are gem minerals; and also where they have been of financial value to the finders, although little or no gem value may be attached to them, as in the case of the Pike's peak amazonstone and smoky quartz, and the Monroe spinels. Many of these are as beautiful, if not more so, in their native form, than they are after having undergone the cutting process, as for example some of the Utah topazes, beryls from North Carolina, and many others, a fact of which almost any one would be convinced by a visit to some of our finer cabinets. The cutting of such material, therefore, for the higher money value, is really vandalism and should be discouraged by all scientists.

A most important find of gem materials and specimens during the past year was at the Auburn, Maine, locality ([a]), which from July, 1883, to July, 1884, afforded possibly about $1,000 worth of tourmaline specimens, and the other minerals netted about $500 more. These were taken out in one month's work, and since then fully $500 more has been realized on those taken out by the various persons working the locality.

The tourmalines and beryls found in the last work done by the Mount Mica Mining Company during the summer of 1882 were still in the possession of the company, and were offered for sale in the summer of 1884 at Bar Harbor, Mount Desert, Maine. Some were there readily sold as

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[a] See paragraph on tourmaline, page 743.

Maine gems. The cut gems owned by the company in the early part of the summer of 1884 were valued by them as follows:

Tourmalines, from $10 to $500 each	$2,683
Beryls and aquamarines, from $5 to $50 each	1,062

There are about $400 worth of uncut specimens. No work was done here in 1884.

The beryl locality at Stoneham (*a*), Maine, has yielded fully $700 worth of gems and specimens to the different workers, one crystal selling at $75 for gem material. Some very fine blue beryls were found here.

The topaz locality, though it produced no topaz, from other minerals yielded the workers over $500 by the sale of herderite, columbite, and associated minerals.

Work was suspended by the mining company at Stony Point, North Carolina, at the end of August, 1883, and was resumed for about two weeks during July of 1884. Since July, 1883, perhaps $500 has been realized from the work done. The work of 1883 brought to light some of the finest crystals that have yet been found, for color, but of secondary gem value. The largest of these was about 3 inches long and very perfect. The two weeks' work of 1884 discovered a few very fine quartz crystals containing rutile, and some containing asbestus or byssolite (?); also very fine rutile crystals, though no gems. When work will be resumed is not definitely known. The adjoining property is reported to have been purchased with a view to working at some future time. The indications on Mr. John Lackey's property look very well for the class of minerals found in this section.(*b*)

Since October, 1882, the Pike's peak topaz and phenakite locality has been searched to some extent, and the topaz and phenakite taken from it thus far would be valued at fully $1,500, one crystal of topaz being held at $100, and one phenakite also at fully this amount. Two topaz gems cut from the stones found here were worth fully the same each after the cutting.

The Crystal peak locality, near Florissant, Colorado, has yielded perhaps $1,000 worth of topaz, some specimens associated with phenakite and on amazonstone, and a number of fine amazonstone crystals.

A number of stones enumerated here, although below 7 in hardness, and even below 6, may suggest to some that they are too soft for any gem or ornamental uses. Thus apatite and fluorite are too soft for cut gems, yet beautiful cups, vases, etc., can be made of the latter. Serpentine and catlinite could be successfully worked where apatite could not, because they are opaque and do not show scratches, and an even, good color will always appear. It is only by adapting any mineral to its proper use that it can be made a success.

One of the finest displays of gem minerals since 1876 was the North Carolina exhibit in the fall of 1883 at the Mechanics' Fair at Boston.

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a "Mineral Resources of the United States, 1882," page 487.

b See paragraph on beryl, page 738.

In this were some of the finest North Carolina quartzes, from White Plains and other localities; remarkably brilliant rutiles from Mitchell and Alexander counties; beautiful amethysts, some of them rutilated; some remarkable Alexander county emeralds, and blue, green, and yellow beryls, and many others that as a rule were quite new to the general public as gem minerals.

Delusive finds.—During the past year a number of articles have appeared in regard to the finding of valuable gems, which have proved otherwise on investigation; and as newspaper statements are at times copied into the literature, it may be well to give them notice from some reliable source.

The "Blue Ridge sapphire," or the "Georgia marvel," as it was called by the press, was found nearly two years ago in a brook in Georgia, in the Blue Ridge mountains. It was estimated to be worth about $50,000 by the owner, who had been assured of its authenticity as a sapphire by two southern jewelers, and arrived at its valuation by taking into account its weight. Anything scratched by a file is sure to be pronounced glass, whether that or really topaz or some equally hard stone; while, on the other hand, the common fallacy may prevail that anything not touched by a file is to be regarded as a genuine stone, even though it may be only glass. In this instance the gem proved to be a piece of rolled blue bottle glass, and its owner could be convinced of this only when he saw a platinum wire coated with a melted fragment of the material.

Another was a stone plowed up by Mr. James M. Smith, of Gibsonville, Guilford county, North Carolina, pronounced a genuine emerald, weighing 9 ounces, by some local expert, who tested it, and with the microscope showed that it contained various small diamonds. Its value was estimated up in the thousands, and $1,000 was reported to have been refused for it by its owner. As it was believed to be the largest known emerald, it was expected by its owner that it would realize him many thousands. Being therefore too valuable to be intrusted to the express company, he put himself to the expense of a trip to New York, where it proved on examination to be a greenish quartz crystal, filled with long, hairlike crystals of green byssolite or actinolite, on which were series and strings of small liquid cavities that, glistening in the sun, led to the included diamond theory of the local expert. As $5 was the best offer received for the stone, it was returned to North Carolina.

The "Wetumpka ruby," from Elmore county, Alabama, the property of Mr. James W. Thomas, was supposed to be a ruby of 6 ounces' weight "after cutting away all the roughness." Owing to its value, it was deposited in the Wetumpka bank vault, and on no consideration would be sent to any one on approbation. A small fragment sent to Mr. L. P. Gratacap, of New York, and examined by him, led him to believe that it was only a common garnet, and from its stated quality of no value, even if a ruby. Doubtless it is one of the large rough garnets so often found in the South.

Another is a quartz (?) crystal found by Mr. James Pepper, of Danbury, North Carolina, which was examined and pronounced to be a genuine diamond by the local jewelers, and valued at $7,000.

The diamond discoveries so often reported are not to be wondered at. In one of the southern States one of the late geologists who had much to say as to the "immutability of human events that would eventually lead to the finding of diamonds, rubies, sapphires, and emeralds in his State," knew so little of the diamond that he actually sent a common paste imitation to New York to inquire as to its genuineness as a diamond. Yet his remarks have often been copied, especially a story that a bottle of diamonds that were worth many thousands of dollars was thrown away before they were recognized.

Utilization of precious stones.—During the last ten years taste in furniture and decoration in the United States has reached so high a degree that every conceivable new idea which has been or is applied anywhere on the face of the earth has been resorted to. Minerals, as a rule, have been only slightly utilized, owing principally to the want of familiarity with them and the methods of applying them so as to avoid coldness and inappropriateness. In one of the finest pairs of carved rosewood silver-paneled pedestals in this country the dull effect of the rosewood was very much relieved by the insertion of a number of small round cabochon pieces of a dark red Texas agate, these additions really giving all the necessary brilliancy where polished wood was an effect not desired. Our large list of cheap and beautiful ornamental stones, such as jasper, agate, silicified woods, turquois, rose quartz, and a large number of others, might be introduced with advantage into the inlaid work on clocks, mantels, and fine furniture. The utilization of rock crystal for hand glasses is mentioned on page 750.

One of the new departures in the United States in the uses made of the common stones is the introduction by a leading New York firm of a line of American stone goods, similar to the Scotch jewelry, the designs of which will be so improved and American gem stones used to such an extent in them that they will undoubtedly find a ready sale, and before the year is closed may be universally sold throughout the United States, displacing many of the cheaper varieties of gold and silver pins. Some of the minerals used are agate, moss agate, jasper of all colors, rhodonite, pyrite, labradorite, Chester county moonstone, and other cheap American minerals. The designs are crowns, knots, thistles, shepherds' crooks, nails, horseshoes, crescents, daggers, keys, spears, umbrellas, and a large variety of others suggested by the variations of forms and colors shown in the kaleidoscope.

The following few items may perhaps be of sufficient interest to entitle them to mention in this report: During the last three years a novelty has appeared in the form of a so-called mineral clock, consisting of a plain wooden case, usually in the form of a house, and completely covered with specimens about an inch square of pyrite, galenite, amazonstone, ores from celebrated mines, and other Colorado minerals. They are glued on, and, as a rule, numbers are pasted on each referring to a list of the minerals on the back of the case. The clock part consists of a Connecticut Yankee clock. They have sold remarkably well since they were introduced, $15,000 worth in 1882, $11,000 in 1883, and $20,000 worth in 1884, to be retailed at an advance of 33 per cent. In addition there are a large number of paperweights, inkstands, and a variety of objects made that have netted several thousand dollars per year more.

Arrow points.—Mr. H. C. Stevens, of Oregon City, Oregon, writes that since 1878 he has personally handled 35,000 fine arrow points, peculiar to Oregon, and that fully 50,000 in all have been found by different persons. Before 1878 perhaps an equal number were found. Fully $3,000 have been realized on these in cash since 1878. At present few are found, except after a heavy freshet and overflow of the river banks, where the greater number have been found. These points at times represent the highest examples of savage stone chipping, and are really so often gem materials that the demand for them as articles of jewelry is not surprising. The prices range from $1 to $2.50 each for the finer ones, which are usually made of rock crystal; flesh-colored, red, yellow-brown or mottled jasper, obsidian, or various colors of chalcedony. They are principally sold in the East, scarcely any being sold in Oregon for jewelry. They are not made by the present Indians of Oregon. Fine suites of Oregon arrow points were exhibited by Mr. M. F. Savage at the Bartholdi Loan Exhibition at the New York Academy of Design, December, 1883.

Trilobite ornaments.—The trilobites found in various parts of the United States are used, when of the proper form, as charms, scarf pins, and other ornaments. Perhaps 99 per cent. of those used for these purposes are found in the vicinity of Cincinnati, especially near Covington, Kentucky. The species is *Calymene senaria*, which, as a rule, are found curled up, evidently in dying, and therefore appear either round or slightly oval in form, making very neat charms, and the smaller ones very pretty scarf pins. They vary in size from one-fourth inch to 2 inches in diameter, and are sold at the locality at from 25 cents to $5 each, according to beauty or perfection. The casts of the *Calymene senaria*, variety *blumenbachii*, if perfectly flattened out and perfect in form, are worn at times as scarf pins. As they are entirely limestone, the surface, as a rule, is covered by thousands of microscopic brilliant crystals of calcite, the glitter of which is very effective. A number of fine trilobites are sold annually at Trenton Falls, especially the *Ceraurus pleurexamthamus* and *Asaphas gigas* from the Trenton limestone. They are sold, however, more as tourists' mementoes than as objects of ornament. Twenty-five dollars is often asked for large fine specimens of the *Asaphas gigas*.

Cat's-eye minerals.—The following minerals found in the United States, when fibrous or cut across the cleavages in cabochon effect, will show the cat's-eye ray:

Corundum: At Ellijay creek, Macon county, North Carolina, Mr. E. A. Hutchins cut a dark brown, almost black, crystal of corundum that furnished a long *en cabochon* gem, two-thirds of an inch across, that shows the cat's-eye ray distinctly.

Chrysoberyl: The chrysoberyls of Stow, Peru, and Canton, Maine, would cut into poor cat's-eyes.

Beryl: The beryls of Stoneham, and some of the North Carolina beryls, especially those from Alexander county, would furnish cat's-eyes, although not fine.

Quartz: Quartz filled with actinolite, from Cumberland Hill, Rhode Island, makes a very fine quartz cat's-eye. This is the Thetis hairstone of Dr. Jackson.

Hornblende: A fibrous black hornblende from near Chester, Massachusetts, afforded an imperfect cat's-eye.

Pyroxene: A white compact fibrous pyroxene from Tyringham, Massachusetts, made a curious white cat's-eye.

Labradorite: Some of the Labrador spar, when filled with included minerals and impurities, will show a cat's-eye ray; this is especially applicable to the mineral found in Orange county, New York, and that also in the northern part of the State.

Hypersthene, bronzite, and enstatite, when fibrous and cut across the fiber, produce a cat's-eye effect, and are sold abroad for this purpose to a very limited extent.

Limonite: Limonite from Salisbury (Connecticut), Richmond (Massachusetts), and other American localities, would at times cut into a gem showing the cat's-eye ray.

Aragonite and gypsum satin spars: These both produce the cat's-eye effect.

LOCALITIES OF PRECIOUS STONES IN THE UNITED STATES.

Diamonds.—Referring to the paper on American gems, in "Mineral Resources of the United States, 1882," containing information furnished by Mr. John H. Tyler, sr., about the Manchester diamond, having since been enabled to obtain a more complete history of it, as it is possibly the largest diamond really found in the United States, I herewith present the facts. The first record I have been able to obtain is from the New York *Evening Post* of April 28, 1855, which says: "We were shown yesterday, on board the steamship Jamestown, what is said to be the largest diamond ever discovered in North America. It was found several months ago by a laboring man at Manchester, Virginia, in some earth which he was digging up. It was put in a furnace for melting iron, at Richmond, where it remained at red heat for two hours and twenty minutes. It was then taken out and found to be uninjured and brighter than ever. It was valued in Richmond at $4,000." This stone was next in the possession of Capt. Samuel W. Dewey, now of Philadelphia, and by him was named the Oninoor or "sun of light," though it has more generally been known as the Dewey or Morrissey diamond. It then passed through many hands. It was cut at an expense of $1,500 by Mr. H. D. Morse, and at one time $6,000 was loaned on it. This diamond was a slightly rounded trigonal trisoctahedron. Its original weight was 23¾ carats, and after cutting it weighed 11$\frac{11}{16}$ carats. As it is off-color and imperfect it is to-day worth not more than from $300 to $400. Exact copies of it in glass, as it was found, and also as cut, were deposited in the United States mint at Philadelphia, by Capt. S. W. Dewey, and also at the Peabody museum in New Haven. Electrotypes of it may be seen in a number of cabinets.

The first diamond found in North Carolina was at the ford of Brindletown creek, by Dr. F. M. Stephenson. It is an octahedron in form, and is valued at $100. Another, in the possession of Professor Featherstonhough, was found in the same neighborhood by him. A third, observed in Mr. D. J. Twitty's collection by General Clingman, and described by Prof. C. U. Shepard, was found at Twitty's mine, Rutherford county. In form this is a distorted hexoctahedron, yellowish in color. A fourth was found by Dr. C. L. Hunter, near Cottage Home, Lincoln county, in the spring of 1852. It is said to be greenish in color and in form an elongated hexoctahedron. Another, in the possession of Dr. Andrews, of Charlotte, was found at Todd's branch, Mecklenburg county. It was said to be a perfect crystal and of a good white color. Dr. Andrews reports also the finding of a black diamond the size of a chincapin by three persons, who crushed it, believing a diamond could not be broken. He found that the fragments scratch corundum very readily.

Dr. Genth reports two diamonds from the Portis mine, Franklin county, one of them a very beautiful octahedron. A small diamond was found on the headwaters of Muddy creek, in McDowell county, and diamonds have also been reported in weight frequently from one-half carat up to over 2 carats, from J. C. Mills's mines, in Burke county. Some of these, examined by Mr. James B. Mackintosh, proved to be quartz, and another supposed diamond, found in some gravel from this mine, in the State collection at Raleigh, I found not to be a diamond, but zircon. The diamonds in North Carolina are usually found associated with gold, monazite, xenotime, zircon, octahedrite, and other minerals. Dr. Genth(*a*) says this débris is the result of the old gneissoid rocks, such as mica-schist and gneiss, in which graphite is always found.

In a letter to the New York *Sun* Mr. C. Leventhorpe mentions the

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a "Mineral Resources of North Carolina," *Journal Franklin Institute*, November and December, 1871.

finding at his placer mine, in Rutherford county, of a diamond of bad color, which was pronounced a diamond and placed in the Amherst College collection by Prof. C. U. Shepard. The same article also mentions a fine white diamond, valued at $400, found in a South Carolina placer by Mr. Twitty, and states that Mr. Twitty has a diamond weighing 3 grains in his possession which was taken in White county, Georgia, from a "long tom."

In the cabinet of Mr. Samuel R. Carter, of Paris, Maine, are two small crystals of diamond weighing less than one-eighth carat, which were found in March, 1866, at the Horshaw placer gold mine, Racoochee valley, White county, Georgia, one by Dr. A. C. Hamlin(*a*), of Bangor, and the other by Mr. H. Ashbury. They are opaque and have no definite form. Several stones of fine quality have been found here.

At the May, 1867, meeting of the California Academy of Sciences Prof. B. Silliman exhibited four diamonds found in California. One, from Forest Hill, El Dorado county, weighing 0.369 gram (= 5.673 grains = 1½ carats), was of good color with a small cavity and a discoloration on one of the solid angles. This crystal, which was not entirely symmetrical, was found at a great depth from the surface, in a tunnel running into the auriferous gravel at Forest Hill. Another was found at French Corral, in Nevada county, weighing 0.3375 gram (= 5.114 grains = 1¼ carats). It was very symmetrical in form, remarkably free from flaws, and slightly yellowish, its color having been altered by having been subjected to a red heat. It had been found in the deep gold washings and was thrown out from the cement. The third was the property of Mr. M. W. Belshaw, weighing 0.2345 gram (= 3.619 grains, little less than 1 carat). This crystal is distorted, and has several reentering angles and cavities. Four others besides this have been found in the search for gold at Fiddletown, Amador county, in the gray cemented gravel underlying a stratum of so-called lava or compact ashes. The other one shown was the property of Mr. George E. Smith, who states that it was found at Cherokee Flat, Butte county, and that he had seen fully fifteen diamonds from this locality; these were all found in the deep gravel washings, and were believed to have come from a stratum 3 feet thick, forming part of a superincumbent mass of material 25 feet thick. Mr. Rèmond (*b*) is quoted as authority for the occurrence of diamonds at Volcano, which may be the same locality as Fiddletown. Professor Whitney at this meeting stated that diamonds had been found at from fifteen to twenty localities in California, the largest that had come to his notice weighing 7¼ carats, having been found at French Corral.

Prof. B. Silliman (*c*) mentions that platinum, almandine garnet, chromite, epidote, gold, iridosmine, limonite, magnetite, pyrite, quartz, rutile,

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a "Leisure Hours among the Gems," A. C. Hamlin, page 49, Boston, 1884.

b "Geology of California," Vol. I., page 276.

c *American Journal of Science*, Vol. 6, 1876.

topaz, and zircon are associated with the diamond at Cherokee, Butte county, California.

Mr. W. P. Carpenter (*a*), of Placerville, states that while he was assisting Mr. W. A. Goodyear, assistant State geologist, in 1871, they found several diamonds in the hands of persons who did not know what they were; one of these was purchased as a specimen by Mr. Goodyear, who had found some specimens of itacolumite 3 miles east of Placerville, but had kept them as curiosities. The gravel in the channel is capped by lava from 50 to 450 feet in depth, and of late years is worked by steam cement mills. He says he knows of instances where fragments of broken diamonds have been found in cleaning up the batteries. He gives the following list of the finders of diamonds near Placerville: Charles Reed and Mr. Jeffries, each one; Thomas Ward & Co., three, two white and one yellow (one of these is now in the possession of Mr. Ashcroft, of Oakland, who had it cut in England); Cruson & Olmstead, four, one(*b*) of which, $\frac{9}{32}$ inch in diameter, was sold to Mr. Tucker, of San Francisco, for $300; Thomas Potts, one small flawed stone, which was sold to Mr. Goodyear for $15; Jacob Lyon, one light-straw colored, about the size of a medium pea, and several fragments from the tailings of a cement mill at the Lyon mine; A. Brooks, one, small white; E. Brentfeld, one, small yellow, weighing two grains, which had passed through a cement mill; one was found by Mrs. Henderson in some tailings that were washed for gold, and is most probably the one mentioned in the 1882 report as having been found near San Francisco.

Mr. H. G. Hanks visited Cherokee Flat, with the intention of studying the celebrated diamond localities, and was informed by Mr. A. McDermott, of Oroville, of a diamond the size of a pea and quite round, which had been sent to him in 1862. They are found in cleaning up the sluices and undercurrents. The first notice of a diamond being found here was in 1853. The largest one, now in the possession of Mr. John More, weighs 2¼ carats, 9 grains. Fifty to sixty stones in all have been found here, of which some were rose-colored and yellow, and others white, and all were associated with zircon, platinum, iridium, magnetite, gold, etc.

Microscopic diamonds were reported from the platinum sands of the Trinity river by Prof. F. Woehler, of Gottingen, with similar associations as at Cherokee. In all the northern counties of California drained by the Trinity river, in the vicinity of Coos bay in Oregon, and on the banks of Smith river, Del Norte county, diamonds may be looked for in the flumes and sluices.

A fine diamond from the Spring Valley mine at Cherokee, Butte county, was presented to the California State museum by Mr. G. F. Williams, superintendent of the mine. Two diamonds from here, one cut and one uncut, are in the possession of Mr. and Mrs. Harris, of

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a Second report of the State mineralogist of California.

b Mentioned in Whitney's "Auriferous Gravels of the Sierra Nevada."

Cherokee. Mrs. W. C. Hendricks, of Morris Ravine, near Oroville, has also a fine Cherokee diamond set in a ring. A diamond found in 1861, weighing 6 grains (= 1½ carats) is now in the possession of Mr. John Bidwell, of Chico. It was from a locality 1½ miles northwest of Yankee Hill, Butte county, and has been cut in Boston.

Mr. C. G. Yale furnishes the following notes on the California occurrences: "For a period of more than thirty years the placer miners of California have occasionally picked up small diamonds. The hydraulic washings at Cherokee, Butte county, have been the most prolific. The diamonds are usually found by the miners when cleaning up their sluices or while washing off the bed rock, though in some few instances they have been picked up on the surface. As a general thing the gravel in which they occur is mixed with lava, ashes, or other volcanic matter; zircon, platinum, iridium, magnetite, etc., being associated with the diamonds. While many of these stones have been of good color, brilliant and perfect, none weighing over 3½ carats have been found in the State. In size they have ranged usually from about half a carat down to stones of microscopic dimensions, the latter being numerous in a few localities. So far as known $500 is the highest price for which any California diamond in the rough has been sold, though large numbers have found purchasers at prices ranging from $10 to $50, and not a few at as much as $100. The stones have been of all colors, white, yellow, straw, and rose, and many of good water. A few small diamonds have been found also in the placer diggings of Idaho, being of about the same quality and occurring under the same conditions as in California. In neither region have diamonds been made the object of special search, those found having been picked up by miners while washing gravel for gold. Fragments of diamonds have been noticed in the tailings from the quartz mills, being the remains of stones which have been broken under the stamps."

Since February, 1884, numerous notices have appeared in the press of the finding of diamonds under very peculiar circumstances. A jeweler of Milwaukee purchased from a lady customer for $1 a stone which he represented as being a topaz. The stone was reported to have been found eight years before at Eagle, Waukesha county, Wisconsin, having been thrown out from a depth of 60 feet while excavating a well. Two small stones are also reported to have been found here, each weighing less than one-half carat, the larger one first found weighng about 15 carats. One of the smaller stones I examined. All three stones are said to resemble those found at the Cape. The 15-carat stone is slightly off-color, and would, therefore, be worth only about $300 at the outside on its merits as a diamond. It has been offered at $1,000, owing to its being the first diamond found in Wisconsin, and it was supposed by the owner that it would be purchased for the State cabinet. Having carefully examined a quantity of the gravel sent to different persons, I have failed to find anything but the regular débris from glacial drift, and, as remarked by one gentleman, believe if the box were to be filled with the drift material from New York City the owner would not discover the difference.

In the latter part of 1883 a diamond was reported to have been found at Nelson hill, near Blackfoot, Deer Lodge county, Montana. This stone is described as being colorless, and in form dodecahedral, with triangular markings, but is more likely a trigonal trisoctahedron with curved faces. Its specific gravity is said to be about 3.5; its weight about 12 grains. It was pronounced by an old diamond dealer of New York as really a diamond. The person now owning it came into its possession through a Chinaman, who panned it out and handed it to him, and he thinks he has seen many similar stones in the mine.

Mr. J. D. Yerrington, of New York, informs me of a brown diamond weighing 1 carat, and yielding when cut a gem weighing one-half carat, which was found near Philadelphus, Arizona. Two pieces of blue bottle glass that had been rolled so as to lose all form, were naturally supposed by the finder to be sapphires, being in the same locality with the diamond.

To insure the finding of diamonds in a new district one of the best methods is to familiarize the searchers with the luster principally, which can be readily accomplished, as once partly carried out by Mr. Dwight Whiting, of Boston. He suggested selling to the miners small imperfect diamond crystals (bort), mounted in a very inexpensive manner, so as that the entire ring or charm could be sold at from $5 to $10. Several thousand searchers thus prepared would soon ascertain whether diamonds really existed, and the crystal would also serve for testing the hardness of the stone as well as the luster. One of the minerals most likely to be mistaken for the diamond is a form of small quartz crystal found principally at Santa Fé and Gallup, New Mexico; Fort Defiance, Arizona; Deadwood, Dakota; and Shell creek, Nevada. They range in size from 1 to 5 millimeters, and the prism is nearly or entirely obliterated. In addition to this, as a rule, the surface is slightly roughened, and by an inexperienced person is easily mistaken for an octahedron, which is almost universally considered to be the only diamond shape.

The well-known "Arizona diamond swindle" was an adroit one, and the locality could hardly have been better selected; but it should not have received so much credence, since gem minerals are so readily recognized by means of their local characteristics by gem-collecting mineralogists.

SAPPHIRE GEMS.

Corundum.[a]—In North Carolina many corundum localities have been opened, and the material found is often of a very fine color even if not of gem quality. It was first found in the State by Gen. T. C. Clingman, who came upon a large dark mass of the cleavable variety, 3 miles be-

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[a] See also page 714 *et seq.*

low Marshall, in Madison county. Later on it was found by Dr. C. L. Hunter in reddish and bluish masses at Crowder's mountain, and also at Chubb's and King's mountains, Gaston county.

The largest deposits of the finest material, however, are those in Macon county, near Franklin (see "Mineral Resources of the United States, 1882," page 485). A very interesting variety from here, in addition to the gems, is a white and blue banded form which would afford curious gem stones. The Culsagee or Corundum Hill vein is from 10 to 14 feet thick. Other Macon county localities are Jacobs & Haskett's mine, on Ellijay creek; Robinson's mine, Sugartown Fork; Houston's mine, and Moore & Higton's mine.

At the Jenks mine, at Franklin, was found probably one of the finest known specimens of emerald-green sapphire (oriental emerald). It is the transparent part of a crystal of corundum 4 by 2 by 1½ inches, from which several gems could be cut that would together furnish from 80 to 100 carats of very fine, almost emerald-green gems (not too dark, as the Siamese), the largest possibly fully 20 carats in weight. As this gem is one of the rarest known, it makes this specimen a very valuable one. It is now in the fine cabinet of Mr. Clarence S. Bement, with a suite of the choicest crystals found at this mine, and its value is over $1,000.

From near Franklin(*a*) a curious brown variety was found which shows a distinct asteria in sunlight or artificial light when the stone is cut *en cabochon.* Similar crystals have recently been found near Franklin by Mr. E. A. Hutchins, and more recently Dr. T. M. Chatard, at a locality 12 miles from Franklin, found a fine dark brown variety with bronze-like reflections.

In the Hogback mine, Jackson county, on the feldspar hanging wall, sapphire is met with in crystals; at the Cullakenee mine at times a deep ruby-red corundum is found, and also at Penland's on Shooting creek, in Clay county. Two miles northeast of Pigeon river, near the crossing of the Ashville road, in Haywood county, and 2 miles north of this on the west fork of Pigeon river, at the Presley mine, are found some of the finest colored specimens of blue and grayish-blue corundum. Twenty miles northeast of this, at the Carter mine, fine white and pink corundum is found in crystals and in a laminated form.

Blue, bluish-white, and reddish corundum is found at Swannanoa Gap, Buncombe county.

Mr. J. A. D. Stephenson found fine hexagonal prisms of a pale brownish corundum at Belt's ridge, and more recently some very fair colors from several new localities near Statesville, North Carolina.

A very fine black corundum crystal is in the Vaux cabinet at the Philadelphia Academy of Natural Sciences, the locality given being Buncombe county, North Carolina. This cabinet has also a fine ruby-

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a Transactions New York Academy of Natural Science, March, 1884.

colored corundum from Buck's creek, Clay county, and another from Hogback, Jackson county.

The gravel deposits of Burke, McDowell, and Rutherford counties contain small grains and crystals of corundum usually altered into damourite.

Mr. E. A. Hutchins, who is doing much to develop the corundum properties of North Carolina, has some very fine opalescent and deep indigo-colored corundum from near Franklin and elsewhere in Macon county.

One of the principal Pennsylvania localities is near Black Horse, near Media, Middletown township, Delaware county; the cleavage plains of the crystals show a bronze luster, and the crystals have usually fixed asterias shown by Dr. Isaac C. Lea(*a*) to be produced by included crystals. They are here found in a feldspathic rock. Near here are also crystals, found loose in the soil, at times 4 to 6 inches in length. After sinking a 60-foot shaft fully 50 tons were mined here, but work has been abandoned.

Mineral Hill, near Media, has furnished large brown and altered crystals.

Near Village Green, Ashton township, Delaware county, large brown crystals have often been found with the brown luster. Dr. Genth mentions a small mass of grayish and blue corundum with good cleavage in the vicinity of the chrome mines, Lancaster county, Pennsylvania.

In Chester county, near Fremont, West Nottingham township, and 2 miles south of Oxford, corundum has been observed with albite. Near Unionville, Newlin township, are several localities of interest, also 1½ miles north of this locality loose crystals 3 to 4 inches in length were found in the soil. (*b*)

Mr. W. W. Jefferis described a new locality on the south side of the Serpentine ridge, in Newlin township, Chester county, and fully 500 pounds of massive blue corundum had been taken out.

Mr. Louis Zimmer, of New York, possesses a fine large crystal of corundum of a deep blue color, found by him 40 miles north of Richmond, Louisa county, Virginia.

Professor Wilson, of Chicago, is reported to have found a large deposit of corundum at Lone mountain, Pennsylvania. Good blue corundum has been found on Sequale creek, Georgia.

Prof. C. U. Shepard (*c*) mentions specimens of asteriated sapphire from Litchfield, Connecticut, lacking, however, the transparency requisite to a good gem.

Hoffmann(*d*) mentions impure columnar corundum in fragments nearly 1 inch in diameter from Silver Peak, Nevada.

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a Proceedings Philadelphia Academy of Natural Sciences, May, 1869.

b Proceedings Mineralogical Section Philadelphia Academy of Natural Sciences, 1879.

c "Report on Minerals of Connecticut," 1837, page 64.

d "Mineralogy of Nevada."

In Dr. F. A. Genth's suite of corundums are some that would afford opalescent stones with fixed stars, and other interesting forms from North Carolina and Pennsylvania. Many fine examples of corundums that would afford mineralogical and interesting gems from Pennsylvania are in the cabinets of Mr. W. W. Jefferis, now of Philadelphia, Mr. Lewis Palmer, of Media, and Dr. Cardesa, of Claymont. Specimens from Pennsylvania and North Carolina are to be found in the cabinets of Mr. Clarence S. Bement, Col. Joseph Wilcox, and Dr. Isaac Lea, and in the W. S. Vaux cabinet at the Philadelphia Academy of Natural Sciences. At present, however, the finest of the sapphires for the gem trade really all come from near Helena, Montana, collected there by the miners in the sluice boxes of the placer mines. These are rolled crystals, rarely over one-quarter to one-half inch long, and the colors are pale but brilliant. In the gravels of the upper Missouri river, in Montana, corundum is also found in placer mining.

The largest known crystal of sapphire(*a*) is the one found at the Jenks mine near Franklin, Macon county, North Carolina, about 1872. It weighs 312 pounds and is both red and blue (ruby and sapphire) in color. It is now in the Shepard collection at Amherst College, and escaped the disastrous fire of 1882, which destroyed so many of the fine objects there.

Chrysoberyl has been found at Stow(*b*), Maine, in masses weighing 5 pounds each, and also in single distorted crystals 3 by 5 by 1 inches, of an opaque color; these may in part furnish very poor chrysoberyl cat's-eyes. Large masses have also been found at Canton, Maine, of a somewhat similar character; and recently, perfect, small, and very distinct crystals of no gem value have been found in fibrolite at a new locality in Stow, Maine. Peru, Maine, has also afforded some crystals, though this locality is now exhausted. Mr. N. H. Perry found one small, very perfect crystal at Tubbs' Ledge, Maine, and it has also been observed at Speckled mountain, and at Stoneham, Oxford county, Maine, near the Stow line, by Professor Verrill; also at Norway.

Rev. Frederick Merrick stated that he had collected fifty years ago some crystals that he believed would furnish gems, but perhaps not of the finest quality, at Haddam, Connecticut, an old and well-known locality, now exhausted. The Greenfield locality, 1 mile north of Saratoga Springs, New York, afforded many beautiful crystals, but is now also exhausted. It was also found in New Hampshire in granite, at the deep cut of the Northern railroad at Orange Summit. None of these localities, however, have furnished a fine gem. The most promising localities are those near Stow, Peru, and Canton, Maine, and gems, if found at all, will be likely to be found here. The alexandrite variety of chrysoberyl has not been observed at any American locality.

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[a] See paper on corundum, *Popular Science Monthly*, Vol. XXII., page 452, February, 1874.

[b] Transactions New York Academy of Sciences, January 22, 1883.

Spinel.—Mr. Silas C. Young, who has collected minerals in Orange county, New York, for over twenty years, writes that in the past he has collected small ruby spinels, also others of a smoky and purple tint sufficiently clear to cut, and that the locality at Hamburg, New Jersey, was discovered by his father over fifty years ago. The region of granular limestone and serpentine in which spinels abound is from Amity, New York, to Andover, New Jersey, a distance of 30 miles. Monroe, Norwich, and Cornwall (New York), and Vernon, Sparta, Franklin, and Hamburg (New Jersey), are well-known localities. The locality known as Monroe, New York, which furnished the monster spinel crystals so well known to collectors of twenty years ago, is really somewhere between Monroe and Southfield. Its exact location was known only to two persons, Mr. Silas Horton and Mr. John Jenkins, both mineralogists, who worked it for some years by moonlight for secrecy, and from it took crystals that realized over $6,000. The locality furnished many fine crystals that were ruined in blasting and breaking out. Since the death of the former miners the position of this most wonderful locality has been unknown. All this region has afforded an occasional gem stone.

The gahnite from the Deak mine, Mitchell county, North Carolina, is of a very dark green color, translucent on the edges, and appears to be compact enough for cutting. The localities of Franklin and Sterling, New Jersey, have afforded some of the finest known crystals of this mineral, which would cut into mineralogical gems. At the lead mine at Canton, Georgia, some fine ones were found on galenite. Dr. F. A. Genth mentions in his "Contributions to Mineralogy" large, rough crystals 9 centimeters long from the Cotopaxi mine, Chaffee county, Colorado. Mr. William Tatham, of Philadelphia, sent me a specimen of gahnite from some lead mine in New Mexico; the crystals were from one-eighth to three-eighths inch across, bright polished octahedrons embedded in galenite. This most interesting and curious association was accompanied with massive garnet. The crystals were translucent on the edges. This locality may rightfully be regarded one of the most interesting for this variety, and it is to be regretted that more exact information cannot be obtained regarding it. At none of these places has this material been found sufficiently fine to make a good gem.

Topaz.—The Platte mountain topaz locality, near Pike's peak, described by Rev. R. T. Cross(*a*) and by Mr. Whitman Cross(*b*), has been prospected very extensively during the last fourteen months, and many fine crystals of topaz have been found, some of them yielding cut stones from 10 to 193 carats each in weight, and in color ranging from colorless to a rich cinnamon brown, and entirely free from flaws. One of the larger ones, belonging to the cabinet of Mrs. M. J. Chase, weighs 125 carats, and is as fine a gem as America has produced of any

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a American Journal of Science, October, 1883.

b American Journal of Science, October, 1882.

kind. These crystals are equal in quality to many of the finest of the same size from Siberia, and one fragment of good color but flawed has been found here which weighed 2 pounds. The crystals found in this locality, over one hundred in all, during fourteen months, have sold for nearly $1,000, at a valuation of from 50 cents to $100 each. At Crystal peak, near Pike's peak, on large amazonstone crystals, topaz is found of a slightly different type, with phenakite, and also different in form, from the Pike's peak variety. Some occur over 1 inch long and quite thick. Prof. J. E. Clayton, of Salt Lake City, visited the locality mentioned, and it was also visited by Lieutenant Simpson in 1847. Here the topaz occurs in some isolated mountains west of the Sevier lake, and 140 miles southwest of Salt Lake City by the road. The rock is an eruptive overflow of trachyte full of amygdaloidal cavities, in which the topaz crystals are found; they are also disseminated through the body of the rock. The crystals are usually small, from 1 to 100 millimeters long, and from 5 to 8 millimeters across. The wine color, yellow, and blue are very uncommon, the general color being limpid white; they are very brilliant and of remarkable transparency, closely resembling the Durango, Mexico, and the Chaffee county, Colorado, varieties, especially the latter, which in the same rock is associated with small fine crystals of garnet. In the scarcity of water the locality presents almost insuperable obstacles, but will no doubt be revisited in the near future. The Stoneham, Maine, locality has furnished scarcely a fair crystal during the year. Genth and Kerr(*a*) mention that the Crowder's mountain topaz is very doubtful, proving on examination to be kyanite. Pycnite occurs in fine columnar aggregations of a yellowish and brownish-yellow color, associated with garnet, near White's Mills, Gaston county, North Carolina.

Diaspore.—Possibly the finest known diaspores are those which were found at the corundum locality near Unionville, in Newlin township, Chester county, Pennsylvania. The crystals were from one-half to 1½ inches in length, and one-quarter of an inch in thickness. The color varies from a white to a fawn color inclining to a topaz, while others are at times of slightly brownish tint. They closely resemble topaz in appearance, and would afford gems as fine as any yet obtained. The finest of these are in the cabinets of Dr. Isaac Lea and Colonel Joseph Wilcox, of Philadelphia.

The emery mines of Chester, Massachusetts, have produced a few small crystals which might be cut into minute cabinet gems.

Mr. John C. Trautwine, of Philadelphia, obtained some minute acicular crystals in a cavity of massive corundum at the Culsagee mine, North Carolina. General T. C. Clingman also observed the mineral associated with blue corundum near Marshall, Madison county, North Carolina.

Beryl and emerald.—Prof. Parker Cleveland (*b*) mentions having seen

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a "Minerals and Mineral Localities of North Carolina," page 53.

b "Mineralogy and Geology," by Parker Cleveland, Boston, 1822, page 341.

several emeralds from Topsham, Maine, of a lively beautiful green color, scarcely, if any, inferior to the finest Peruvian emeralds; also two (*a*) rose-colored beryls as having been found at Goshen, Massachusetts. The finding of an emerald at Haddam, Connecticut, of a deep green color, an inch in diameter and several inches in length, is mentioned in Bruce's *Mineralogical Journal*, Vol. V., 1, as belonging to Colonel Gibbs' cabinet.

As no true emeralds are in existence from Haddam or Topsham, these may really refer to very dark green beryls.

Of emerald specimens some of the finest in color, though of little gem value, were found during the summer of 1883 at the Stony Point mine, in North Carolina. The finding of fine beryls and emeralds of pale color collected by Mr. J. A. D. Stephenson on the property of J. O. Lackey, 1 mile southwest of the Stony Point deposit, and a short distance from the Lyons property, on which the same mineral was found by Mr. Smeaton, of New York, shows that the deposit is evidently not accidental, and that there is encouragement for future work in this region. Beryl is found in greenish-yellow and deep green crystals, resembling the Siberian, in the South mountains 9 miles southwest of Morganton, Burke county; in the Sugar mountains at Shoup's ford, Dietz's, Huffman's, and Hildebrand's, and in smaller crystals in Jackson county. One fine blue-green crystal in quartz was found at Mills's gold mine, Burke county, and one fine transparent green crystal from near here is now in the cabinet of Mr. M. T. Lynde, of Brooklyn. Fine blue-green aquamarine occurs at Ray's mine on Hurricane mountain, Yancey county, North Carolina. Clear green beryls have been found at Balsam Gap, Buncombe county; Carter's mine, Madison county; Thorn mountain, Macon county; E. Balch's, Catawba county; Fort Defiance, Caldwell county, and at Wells, Gaston county. Some crystals 2 feet long and 7 inches in diameter, that would cut into gems with small clear spots, occur 4 miles south of Bakersville creek, and still others, larger, at Grassy creek, North Carolina.

The Stoneham, Maine, beryls have flocculent centers, with fibrous appearance, and some of these may cut into beryl cat's-eyes.

Beautiful transparent beryls have been found at Streaked mountain, Norway, Lovell, Bethel, and Franklin plantation, Maine, and very good ones also at Mount Mica and Grafton, Maine. The best locality, however, is the one at Stoneham, mentioned in the last report.(*b*) Here some perfect gems over 1 inch long were cut from the material, and the work during the last year has yielded aquamarines of a good blue color, the aggregate values of which amount to over $700.

At Albany, Maine, Mr. N. H. Perry has recently found beautiful transparent golden yellow beryls that would cut into perfect gems of over

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a "Mineralogy and Geology," by Parker Cleveland, Boston, 1822, page 344.

b "Proceedings American Association for the Advancement of Science," 1883.

2 carats each. One fine-cut light sea-green aquamarine beryl from Sumner, Maine, in Mrs. Merchant's cabinet, weighs about 7 carats.

One remarkably fine deep-blue gem from Royalston, Massachusetts, weighing over 10 carats, is in the United States National Museum, and in the same collection is one weighing 14 carats from Portland, Connecticut, equal to almost any from Brazil for depth of blue color. Both of these localities have at times afforded fine clear material. Some very clear white stones are obtained at Pearl hill, in Fitchburg, Massachusetts, and are sold by the local jewelers. Dr. A. C. Hamlin owns a very fine golden yellow beryl of 4 carats from this locality.

Fine crystals of beryl of almost emerald green color, also beautiful yellowish green and bluish beryls, are found in Deshong's quarry, near Leiperville, Pennsylvania; the crystals are at times 12 inches long, of a yellowish green color. At Shaw & Ezra's quarry, near Chester, at Upper Providence, and in Middletown, Concord, and Marple townships, fine specimens have been found. Fine beryls also have been observed at White Horse, 3 or 4 miles below Darby, Pennsylvania. Bluish green and blue beryls occur in the vicinity of Unionville, Newlin township, and on Brandywine battlefield, in Birmingham township. One crystal, of a dark tourmaline green tint, over one-half inch long, in the cabinet of Mr. Michael Brodley, of Chester, Pennsylvania, is from Middletown, Delaware county, and would afford a fine gem. Some of the gems from here, especially those from the John Smith farm, have much the appearance of bluish emeralds. The finest American golden yellow beryls are found at the Avondale quarries, Delaware county, Pennsylvania. A 20-carat gem is in the cabinet of Mrs. M. J. Chase, and material for another is in the cabinet of Mr. Clarence S. Bement. Mr. B. B. Chamberlain has lately found six fine yellow beryls, 1 to 2 carats each, in Manhattanville, New York City.

The variety of beryl found at Goshen, Massachusetts, and called goshenite, occurs in pieces transparent enough to afford gems.

Phenakite.—About fifty crystals of phenakite have been found during the last year, of which fully one-quarter would aoffrd gems, some over 6 carats in weight and absolutely pellucid; the largest crystal found was 3 inches across; the finer ones are equal in quality to the Siberian. They have been observed at the locality near Pike's peak(*a*), and also near Crystal peak small ones on amazonstone. At the topaz locality at Florissant, El Paso county, Colorado, phenakite(*b*) occurs in small but very interesting crystals implanted on microcline amazonstone. They are rarely over 5 millimeters in size, and are very transparent and colorless, and would afford minute gems.

Euclase.—Only one mention is made of euclase in the United States.(*c*)

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a W. Cross, in *American Journal of Science*, October, 1882.

b Identified by Mr. W. Cross in December, 1884.

c "Minerals and Mineral Localities of North Carolina," 1881.

In this case several crystals were reported as found at the residence of Mr. Morrill, Mills's Spring, Polk county, North Carolina, by Gen. T. L. Clingman, in washing the gold sand at this locality, and Dr. F. A. Genth says this mineral was *not* euclase.

Zircon.—At a locality near the Pike's Peak toll road, due west from the Cheyenne mountains (*a*), zircons are found in a soft yellow mineral in a quartz rock. The crystals found here are the most beautiful ever found of this mineral, nearly always brilliant and often transparent; in color generally a rich reddish brown, although at times pink and honey-yellow, some few emerald-green crystals also having been found. They are rarely over one-eighth inch in diameter, as a rule not over one tenth, and yet some of them would furnish very interesting small gems. Opaque zircon is found at several localities in the Pike's Peak district, in one case associated with amazonstone and in another with astrophyllite, also with a flesh-colored microline in the same region, and in a quartz rock. No gems have been found in these localities. Zircon is abundant in the gold sands (*b*) of Polk, Burke, McDowell, Rutherford, Caldwell, Mecklenburg, Nash, Warren, and other counties in North Carolina, in nearly all the colors peculiar to Ceylon; yellowish brown, brownish white, amethystine, pink, and blue. They have many planes, but are too minute to furnish gems of any value. Gen. T. L. Clingman, in 1869, obtained within a few weeks 1,000 pounds of the well-known brownish crystals from Buncombe county, North Carolina. They occur in equal abundance at Anderson, South Carolina. The latter are readily distinguished from the North Carolina crystals, being much larger, often 1 inch across, and the prism is nearly always very small, the crystal being made up often of the two pyramids only.

Fine crystals of this mineral have also been found in Lower Saucon township, Northampton county, Pennsylvania, and three-fourths of a mile north of Bethlehem. The gravels of the Delaware and Schuylkill rivers contain considerable quantities of very minute nearly colorless crystals of zircon. Some fine ones over 1 inch in length have been found at Litchfield, Maine, and all through the cancrinite and sodalite rocks near them. In the Canfield cabinet are some of the finest known black zircons, perfect crystals over 1 inch long, which were found near Franklin, New Jersey.

Andalusite.—The andalusites of Upper Providence, Delaware county, Pennsylvania, described by Prof. E. S. Dana (*c*), are worthy of mention from the fact of their remarkable size, one of the crystals weighing 7 pounds, although not fit for gem purposes.

Andalusites of a fair pink color not entirely perfect, but still of a quality to produce mineralogical gems, were found to some extent at

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a *American Journal of Science*, October, 1882.

b "Minerals and Mineral Localities of North Carolina," 1881, page 44.

c *American Journal of Science*, III., Vol. IV., December, 1872.

Westford, Massachusetts(*a*), some of the crystals being 2 inches long and one-fourth inch across.

No new crystals have been found at the Gorham, Maine, locality(*b*), of which a brief mention was made in the last report.

Andalusite has been found on the slope of Mount Wiley, Standish, Maine, by Mr. Lucien Holmes, of Standish; the crystals are fully one-quarter to three-eighths of an inch in diameter and of a good flesh-pink color; they would cut into very fair mineralogical gems. While collecting on the Dresser farm, back of the Lucien Holmes farm, I found some crystals similar to the above, equally as transparent, associated with crystals of pyrrhotite in a quartz ledge. The locality associations being identical at the three places, although 6 miles apart, would lead to the inference that this mineral must occur in some abundance in this vicinity, and that these are only outcrops of the same rock, which may yield some fine gems if the proper amount of work be expended there.

Prof. W. P. Blake (*c*) first observed that in Mariposa county, California, in the drift of the Chowchilla river, near the old road to Fort Miller, chiastolites are found in great abundance in fine crystals, showing the dark crosses on a white ground in a remarkably perfect and interesting manner. They are also found in the stratum of conglomerate which caps the hills above the streams, and these were doubtless all originally in place in the slates a little higher up the river. Smaller and less perfect "macles" are found in the slates at Hornitos on the road to Bear valley. The Mariposa, California, crystals, are rather the finer.

The interesting and well-known illustrations in Dana's "System of Mineralogy," page 372, well indicate the endless variety of markings that may exist in this mineral and the beautiful ornamental effects that could be produced, serving also purposes of personal adornment.

Lancaster and Westford, Massachusetts, have produced many of the finest "macles" ever found.

Schorlomite.—The schorlomite of Magnet Cove, Arkansas, as a rule is penetrated by white crystals of apatite, but at times is very free from all foreign matters, and very compact, breaking with a very bright conchoidal fracture. Its superior hardness impressed me enough to try and see the effect in gem form. It proved on cutting to yield a dead black stone of not quite as metallic a luster as rutile, but rather a modification between it and black onyx. As it occurs in sufficient quantity we have here material that will form a new and fine mourning gem; stones can be cut of any size to perhaps over 20 carats, as the mineral occurs to fully this size. The first stone cut was over 6 carats in weight. It is the only gem of metallic luster over 7 in hardness.

Staurolite.—The staurolite of Fannin county, Georgia, 12 miles south-

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[a] School of Mines cabinet, New York.

[b] "Proceedings American Association for the Advancement of Science," 1883.

[c] W. P. Blake: "Mineral Localities of California," 1866.

east of Ducktown, Tennessee, first described by Prof. E. S. Dana(*a*), has furnished some of the finest known twinnings of this material. From their beauty these have found a sale abroad as ornaments and charms, and are more highly regarded than those found at Bretagne, France, which the superstitious believe were dropped from Heaven, according to the legend. They occur twinned in single and double crosses, and large quantities were found in decomposed rock, of which perhaps one-tenth were perfect crystals. They usually require a certain amount of scraping and cleaning when found.

Some fine brilliant crystals are found at Windham, Maine, some of the twins forming fine crosses. Occasionally crystals are found here that would afford small mineralogical gems, if cut. Their use for natural ornaments is exceedingly limited abroad, and here they are used scarcely at all.

Staurolite is found also at Franconia and Lisbon, New Hampshire, in mica slate; on the shores of Mill pond, loose in the soil; at Grantham; at Cabot, in Vermont; at Chesterfield, Massachusetts; at Bolton, Litchfield, Stafford, Tolland, and Vernon, Connecticut; on the Wissahickon, 8 miles from Philadelphia, in abundant reddish brown crystals; and at Canton, Georgia, at the lead mine.

It is also found at the Parker mine, Cherokee county, North Carolina, in fine twins; also on Persimmon, Hanging Dog, and Bear creeks, Madison county, and Tusquitee creek, Clay county. At the latter localities it is found in argillaceous and talcose slates.

Some staurolite macles similar to a chiastolite are described by Dr. C. T. Jackson from Charlestown, New Hampshire, which by insensible shades pass into andalusite macles.

Iolite.—The late Dr. Torrey possessed a fine seal made of a cube of iolite from the albite granite of Haddam, Connecticut, that displayed its dichroitic properties to the greatest perfection, the blue being remarkably fine. Though this locality promised well, the supply of gem material was scant. It has been found near the Norwich and Worcester railroad, between the Shetucket and Quinnebaug, where the gneiss has been quarried for the road. At Brimfield, Massachusetts, on the road leading to Warren, it occurs with andalusite in gneiss, and also near Norwich, Connecticut. It is found also at Richmond, New Hampshire, with anthophyllite in a talcose rock. No gems are being found at present.

Tourmaline.—One of the remarkable tourmaline localities(*b*) of the world is Mount Apatite, on the Hatch farm, Auburn, Androscoggin county, Maine, the locality first discovered by Mr. S. R. Carter. It was worked by Mr. N. H. Perry, who first found the true vein in 1882, and obtained probably one thousand five hundred crystals. They are

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a American Journal of Science, Vol. XI., May, 1876, page 385.

b American Journal of Science, Vol. XXVII., April, 1884. "Proceedings American Association for the Advancement of Science," 1883.

usually colorless, light pink, light blue, bluish pink, light golden, and sections show the characteristic variety of color, such as blue and pink, green and pink, when viewed through the end of the crystal. Some of the faintly-colored crystals afforded gems that were considerably darker after the cutting.

During the last summer the north side of this locality has been worked by Mr. G. C. Hatch and Mr. T. F. Lamb, and much darker material has been found, especially the green colors, some of which equal anything found at Mount Mica. Rude black crystals were observed here 8 inches in diameter and 12 feet long, and at times inclosing quartzite. Several specimens were almost emerald color, and would afford gems. This promises well to afford fine gems for some time to come, as well as the Mount Mica locality.

Mr. Lucien Holmes, of Standish, Maine, found crystals of green, red, and blue tourmaline on the Hussey farm, but they were not of gem quality, although very good as crystals. As little work has been done, this locality might improve by development. The specimens at Bates College, Lewiston, labelled "Baldwin," are supposed to have been found at this locality.

During the last year Mr. E. G. Bailey and Dr. A. C. Hamlin have opened the Mount Black locality at Rumford and Andover, Maine. The indications here are quite good for gems, and a quantity of rubellite, a great quantity of lepidolite, spodumene 3 feet long, cookite, amblygonite, and other minerals similar to those of the Mount Mica, were taken out, none however of gem quality.

The tourmaline mentioned in Hamlin's "Tourmaline," page 72, was found about 1860, by Augustus Lane, at Welcome's Corner, on the Boutelle farm. This specimen was first recognized by Dr. Hoar. The locality is about half a mile from the Hatch farm, and the indications were found by Dr. Hamlin on working, in 1860 and 1862, to be the same as at the Hatch farm.

The localities in Maine that have furnished fine tourmalines are Mount Mica at Paris, two localities at Auburn, Hebron, Norway, Mount Black in Andover and Rumford, as well as the Standish locality; the two latter have furnished no gems.

Some of the finest of the cut rubellites and green tourmalines are in the possession of Prof. C. U. Shepard and members of his family. One of the most magnificent known green tourmalines is one, the color of which is described by Professor Shepard as of a chrysolite-green, and having a blue tinge, while less yellow and more green than chrysolite. It is 1 inch long, $\frac{3}{4}$ inch broad, and 1 inch thick, and finer than any of the Hope gems. One fine rubellite of two-thirds this size, and equally fine, one pink topaz one-half this size, and one remarkable rubellite the size of the large green tourmaline, are also in possession of this family.

The Hamlin cabinet [a], the first crystal of which was found in 1820,

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[a] See "The Tourmaline," by A. C. Hamlin.

contains many hundred fine rubellites, indicolites, achroites, and fine pink, green, yellow, and other colored tourmalines, mostly from Paris, Maine. It is the finest tourmaline collection in the world, and really would furnish full suites for a dozen cabinets. One wonderful dark gem of 28 carats, 1 inch long, one achroite of 23 carats, and many fine stones of nearly every known shade of color of this gem, are found in this cabinet.

The DeKalb, New York, locality of white tourmalines afforded a few fine crystals. The choicest of these, in the cabinet of Mr. Clarence S. Bement, is over 1 inch long, and would cut into a gem weighing over 10 carats, that for light yellow color would be equal to that from any American locality.

Dr. Genth(*a*) mentions beautiful light yellow, brownish yellow, and at times white crystals, at Bailey's limestone quarry, East Marlborough, Pennsylvania; yellow crystals at Logan's limestone quarry, West Marlborough; brown, light yellow, at times transparent, at John Nivin's limestone quarry, New Garden township; and green tourmaline in talc has been found near Rock Spring, Lancaster county. Very beautiful crystals of black tourmaline are found in Delaware county; near Leiperville, it is found in crystals of 5 inches in length and 1½ inches thick, and well terminated; also in Marple township, terminated with two low rhombohedra. These are about as fine as black crystals are ever found. Bluish and brownish green tourmaline is found in fine crystals, penetrating damourite and diaspore, at Unionville, Newlin township.

The brown tourmaline found near Amity, and called xanthite, Mr. S. C. Young informs me he has observed transparent enough to cut into gems.

A small, well terminated, transparent green tourmaline (*b*) was found by Colonel Mills, on Silver creek, Burke county, North Carolina; also a black crystal 4 inches long, inclosed in a green beryl crystal.

Garnet group.—Although the garnets found in the diamond mines at the Cape of Good Hope, the so-called Cape rubies, are larger in size, and perhaps equal to those of Arizona, New Mexico, etc., by daylight, yet there is undoubtedly no finer garnet found that looks better in the evening than those from the garnet regions of the United States. The dark color in Cape garnets remains by artificial light, whereas with the American garnets nothing but the clear blood color is visible. They are of fine quality and plentiful on the Great Colorado plateau. Hoffmann mentions good though small crystals of garnet from Black Cañon, Colorado river, Nevada. Fine small almandine garnets are also found in the trachyte of White Pine county, Nevada. Some very fine crystals of garnet have been found during the summer at Round mountain, Albany, Maine, by Mr. Edgar D. Andrews. The large dodecahedral and trapezohedral garnets, coated externally with a brown crust of

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a "Preliminary report on the Mineralogy of Pennsylvania," page 96.

b "Minerals and Mineral Localities of North Carolina," page 52.

limonite, but usually on breaking showing a bright and very compact material, are often as fine in color as the Bohemian gem material, and should find a ready use for watch jewels and other like purposes. Some of these crystals weigh 20 pounds, and would afford large dishes or cups measuring from 3 to 6 inches across. Some have been cut into very fine gems. They are found in Burke, Caldwell, and Catawba counties, North Carolina. A very large quantity has been found about 8 miles southeast of Morganton, in Burke county, and also near Warlick, in the same county. Another good locality is 4 miles from Marshall. Many of them are very transparent, varying in color from the purple almandine to a pyrope red. Many tons have been crushed to make "emery" and the sandpaper called garnet paper. The peculiar play of color is often due to the inclusions. In these, as well as those from Stony Point and elsewhere, at times nearly one-quarter of the entire crystal is taken up by cavities of fluid, acicular crystals, etc.

Pyrope of good color has been observed in the sands of the gold washings of Burke, McDowell, and Warren counties, North Carolina.

The Avondale, Pennsylvania, quarry has furnished some of the finest known crystals of common garnet as specimens, one of them measuring 2½ inches across (in a piece of quartzite), in color a rich purplish red, with beautiful natural polish and remarkably sharp angles. It is, perhaps, as fine as it is possible for this mineral to occur in crystal form, and is in the cabinet of Mr. C. S. Bement.

Iron-alumina garnet is found in Concord township, at Deshong's quarry, Shaw & Ezra's quarry, and at Upland, near Chester; also in Darby, Acton, Lower Providence, Haverford, and Radnor townships, Pennsylvania. A dark red variety, similar to pyrope in color, is found in the bed of Darby creek, near the Lazaretto, in Delaware county. Some peculiar garnets of a deep blood-red color have been mistaken for pyrope, but an analysis made by Mr. C. A. Kurlbaum proved them to be true garnets. Many garnets have been cut by collectors from both Chester and Delaware counties, and some of these were of very fair quality. At Acworth, Grafton, and Hanover, New Hampshire, garnets of gem value have often been found. At Russell, Massachusetts, a vein of garnet, very dark in color, and called there black garnet (not melanite), was opened during the last two years, and many fine crystals have been taken out, partly by Mr. Daniel Clark, of Tyringham, Massachusetts. These have been sold as specimens only, or exchanged for minerals, and were valued at fully $1,000 in all.

Beautiful transparent essonites one-fourth inch in diameter have been found at the Avondale quarry, Pennsylvania. They are entirely transparent and quite flat, being usually found between plates of mica. A few have been found equal to the Ceylon essonites. Essonite has been found of good quality at Milton plantation, and at the Carter, Perry, and Wild properties, Oxford county, Maine. Very fine essonites, red and fine yellow, were formerly found at Phippsburg, Maine. Mr. George

W. Fiss, of Philadelphia, found some of the most beautiful natural gems of microscopic yellow garnets in the cleaning out of a small cavity at the microlite locality near Amelia Court-House, Virginia. In the cabinet of Dr. Isaac Lea are some crystals of a rich, dark, oily green grossularite, transparent, from 1 to 5 millimeters long, that were found at the Good Hope mine, California. Some very fair crystals of a rich green grossularite, from 1 to 5 millimeters in diameter, are found at Hebron and West Minot, Maine.

The colophonite from Willsborough, New York, although of a beautifully rich, irridescent color, has never been utilized, owing to the small size of the grains and the friability of the large masses. At Franklin, Sussex county, New Jersey, immense crystals of the different varieties, melanite, polyadelphite, colophonite, etc., have been found, but rarely in crystals that would afford a gem.

The beautiful and rare garnet, ouvarovite, was first described as occurring in this country by Prof. C. U. Shepard(*a*), as having been found in minute nearly transparent emerald-green crystals one-tenth inch in diameter at Wood's chrome mine, Lancaster county, Pennsylvania. The ouvarovite from Oxford, Canada, adjoining Newport, Vermont, on Lake Memphremagog, is found in large quantities, at times in masses over 1 foot across. The crystals, however, are very small, being rarely over one-sixteenth inch across, though usually of a good color. The white garnet from here, described by Dr. T. Sterry Hunt(*b*), although not in crystals, is identical with the fine crystals found at Wakefield(*c*), Canada, and has been cut into white gems. The Wakefield ouvarovite is much finer than the Oxford crystals, some one-fourth inch across having been found, one of which is now in the cabinet of the late Mr. John G. Miller, of Ottawa, Canada.

Garnets are found at many localities in California and Arizona. According to Prof. W. P. Blake they have been found at the following places in California: Rodgers mine, in the eastern part of El Dorado county, a green grossular stone in copper ore; near Petaluma, Sonoma county, associated with specular iron, calcspar, and iron and copper pyrites; in the Coso district, Inyo county, in large semi-crystalline masses of a light color, some specimens of which were taken to San Francisco under the impression that they contained tin; 3 miles from Pilot Hill, El Dorado county, in blocks several feet thick; also in Plumas, Mono, Fresno, Los Angeles, and San Diego counties. Garnets occur in great quantities in mica-schist at the mouth of the Stikeen river, near Fort Wrangel, Alaska. Blood-red stones are plentiful on the Nacimiento desert, near Fort Defiance, northeastern Arizona. They are found here in the loose sand, having probably been brought by the action of water from a point 50 miles to the north, where they occur in

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[a] *American Journal of Science*, 2, XLI., page 216.

[b] "Geology of Canada," 1863, page 496.

[c] "Proceedings American Association for the Advancement of Science," 1883.

the so-called syenite. This is thought to be the place where the perpetrators of the famous "diamond swindle" procured the garnets with which they salted the bogus diamond field. In the western part of Arizona, on the same parallel with Fort Defiance, garnets have been observed on both sides of the Colorado river.

Kyanite.—The finest American kyanites were possibly those formerly found at Chesterfield, Massachusetts, a fine example of which is in the British Museum cabinet at South Kensington. The crystals in this are all distinct, of a fine dark blue color, and would cut into some small mineralogical gems.

At the locality at Derby creek, Moon's ferry, Delaware county, Pennsylvania, fine deep azure-blue blades 5 and 6 inches long have been found, which would afford gems if they were thicker. Blue, green, and gray specimens are found at East Bradford.

Fine crystals are found, together with lazulite, at Chubb's and Crowder's mountains, Gaston county, North Carolina, on the road to Cooper's gap.

In Maine kyanite is found in fine crystals at Windham.

The old localities are Worthington, Blanford, Westfield, and Lancaster, Massachusetts; Litchfield and Washington, Connecticut; Stratford, Salisbury, and Bellows Falls, Vermont; near Wilmington, Delaware, and at Willis mountain, Buckingham county, also 2 miles north of Chancellorsville, Spottsylvania county, in Virginia.

No really fine gems have as yet been produced from American kyanite.

Danburite is found in considerable quantity at Russell, New York.

Lithia emerald (*hiddenite*).—Lithia emerald, or hiddenite, has been found in very small quantities at Stony Point, Alexander county, North Carolina, since the spring of 1883; nearly all the gems sold by the company now are, therefore, of old material, usually small stones, or else rather light colored.

SILICA GROUP.

Transparent quartz.—In Herkimer county, New York, quartz crystals have been collected by many for their remarkable brilliancy and perfection, rivaling even those found in the Carrara marble; many collections of them have been made, notably one by Rev. Bogert Walker, of Herkimer. There are a number of others at Middleville, Little Falls, Canajoharie, and other places. Many are sold along the railroads, a two-ounce vial of them usually bringing $2. Crystals with a drop of water bring from $1 to $30; single fine limpid ones, from 10 cents to $25. At times they are brilliant, transparent, and perfect as any known substance, whiter even than any diamond. Curious groupings or inclusions, such as bitumen, pearl spar, etc., also bring fancy prices.

Many fine crystals were obtained where the railroad was opened, at Middleville and Newport, also at Little Falls, on the line of the West

Shore railroad. The old diggings at Little Falls have been worked so extensively that the highway has been encroached upon, thus partly preventing further digging. There crystals are in demand all over the United States, several men being required to dig nearly all the time to supply the demand from all quarters. At Diamond point and Diamond island, Lake George, the same crystals occur as in Herkimer county, and are extensively sold there.

Some of the most magnificent known groups of quartz were formerly obtained at the Ellenville lead mines, Ulster county, New York, some of the finest of which are now at the American Museum of Natural History, New York City. Few, if any, of these were used for gem purposes, although many were sold as souvenirs at the locality over twenty years ago. The Sterling mine at Antwerp, New York, furnishes small, fine, doubly-terminated dodecahedral crystals, and the same forms, slightly different, are also found in the specular iron at Fowler, Herman, and Edwards, Saint Lawrence county; Diamond hill, Lansingburg, is an old but poor locality, and Diamond island, Portland harbor, Maine, is well known for the small but bright crystals found there.

Dr. Genth, in "Preliminary Mineralogy of Pennsylvania," mentions crystals from 1½ to 3 inches across, short and thick, but with clear pyramid, from Nazareth, Northampton county, Pennsylvania; also fine crystals, 1½ inches long and wide, from Crystal springs, on Blue mountain, in Bushkill township.

The highly modified crystals from Diamond Hill and Cumberland Hill, Rhode Island, also the fine ones from White Plains and Stony Point, Alexander county, and from Catawba and Burke counties, North Carolina, are worthy of mention, and lately formed the subject of a crystallographic memoir by Prof. Gerhard vom Rath.

The San Francisco *Bulletin* of July 16, 1884, mentions the finding of a large deposit of crystal or pebble stones on the Santa Margarita rancho, San Diego county, California, special reference being made to one specimen of pure crystal 8 inches in diameter.

Mention is made by Dr. Daniel G. Brittou(*a*) in a paper on the folk lore of Yucatan, in quoting the language of Garcia that the natives were converted from Pagan idolaters to Christian idolaters, and speaking of the belief in witchcraft and sorcery among them, that the wise men divine with a rock crystal and that it has great influence over their crops. Their occurrence in the mounds of Arkansas, North Carolina, and elsewhere, and the abrasion of the crystalline edges, would lead to the inference that they were not collected only to bury with the dead, but that they were carried by the natives for a long time to produce certain influences, and having been used for such purposes were probably buried with them as their property. Personal observation in Garland and Montgomery counties, Arkansas, carried on at times 40 miles from the Crystal mountain locality, showed these crystals

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a Folk Lore Journal, August, 1883.

associated with a quantity of some of the finest chipped arrow points of chalcedony anywhere found, and yet no trace of a chipped crystal could be found among them. In a number of the mounds leveled by the farmers in cultivating, and not worked systematically, many single crystals of quartz were revealed, which may, however, have been kept for their beauty and symmetry by the Indians. These masses of transparent quartz, especially from North Carolina, would afford perfectly clear crystal balls, at least 2 to 4 inches in diameter, and a few have been cut over 2 inches.

A large mass weighing 5 kilos was recently brought from Alaska, and was only a part of an original mass which must have weighed 20 kilos. It afforded clear crystal slabs for hand glasses 3 by 5 inches. The superiority of this material over glass lies in the fact that it does not, like glass, by its color detract from the rosiness of the countenance. A fine glass of this kind is in the Dresden "green vaults."

Amethyst.—One of the finest American amethysts was lately shown me by Mr. L. M. Ives, of New York City. The color was nearly equal to the finest Siberian, and the crystal would afford a gem three-eighths inch arcoss. It was found by Mr. Ives, 1½ miles from Roaring brook, near Cheshire, Connecticut.

Amethyst of a light purple and at times pink color is found in crystals 3 inches long and over in large abundance at Clayton, Rabun county, Georgia. At times these have large liquid cavities containing movable bubbles of gas. They are of little gem value, although fine as specimens. Some fine amethysts in the Hamlin cabinet are from Oxford county, Maine. Very fair crystals were formerly found at Mount Crawford, Surray, Waterville, and Westmoreland, New Hampshire. Some very fair crystals have been observed at Bristol, Rhode Island. Dr. F. A. Genth(*a*) mentions magnificent specimens from Delaware and Chester counties, Pennsylvania. Among the principal localities may be mentioned the farms of S. Entrikin, William Gibbon, Mrs. Faulkes, and Dr. Elwayne, in East Bradford township; in Pocopson township, John Entrikin's and Joseph B. Darlington's; Birmingham township, on Davis B. Williams's farm; in Charlestown township about 1 quart of loose crystals were obtained; on Charles Passmore's farm, Newlin township, about 100 pounds have been found. Mr. W. W. Jefferis(*b*) announced that amethysts of a rich purple color had been found in the northern part of Newlin township. Splendid crystals, one weighing 7 pounds, though not gem material, were found at Morgan Hunter's farm in Upper Providence. Other localities are Astor, Concord, Marple, and Middletown townships. Near Twaddle's paper mill, in Birmingham, they are found in clusters, and in isolated crystals near Dutton's mill;

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a "Preliminary report on the Mineralogy of Pennsylvania," page 57, B.

b "Proceedings Philadelphia Academy of Natural Science, Mineralogical Section," page 44.

also at Chester and Thornbury, Delaware county, Pennsylvania, where many fine gems have been found, well known among the cabinets.

Hoffmann mentions amethyst on the mesa near the mouth of the Rio Virgen, Nevada. In Llano and Burnett counties, Texas, some very fair amethysts have been found; and at Grand Rapids, Wood county, Wisconsin, also in the amygdaloid on the Lake Superior shore, and in Michigan in trap rock at Keweenaw Point and Point Aux Peaux, Monroe county.

In the Yellowsone National Park and at Holbrook, Arizona, amethysts line the hollow trunks of agatized trees, varying in color from light pink to a dark purple, and forming a beautiful contrast with the chalcedony and banded agate sides of these specimens. They occur also in small crystals at Nevada and neighboring localities on Bear creek, Clear Creek county, on the summit of the range east of the Animas, Colorado. The Lake Superior variety found at Prince Arthur's landing, often of large size, is spotted with the coating of red mosslike markings so well known, giving them a moss-amethyst effect, if cut, though as a rule the coating is so even as to cover the entire surface, and nothing but a brick-red color is visible unless the crystals are broken. Notwithstanding the abundance of this mineral, but few gems could be cut from this locality. The West Shore railroad tunnel at Weehawken, New Jersey, brought to light a few very fair amethyst specimens in the volcanic rock.

The most remarkable amethyst as yet found in the United States has lately been deposited in the National Museum by Dr. H. S. Lucas. It is a turtle-shaped prehistoric chipping, measuring 2¾ inches in length, 2 inches in width, and 1½ inches in thickness. The entire piece is transparent, flawless, and would afford a remarkable gem if cut.

Citrine is mentioned by Hoffmann(*a*) as occurring at Tuscarora, Gold Mountain, and in Palmetto cañon, Nevada. At Taylorsville and Stony Point, North Carolina, a number of clear pieces of this material were found that cut fair stones weighing over 1 ounce each. Occasionally at the Herkimer and Lake George localities quartz crystals have a fine citrine tint.

Smoky quartz.—The quartz of Herkimer county, New York, and Diamond island and Diamond point, Lake George, is at times of a variety of beautiful smoky tints and exceptionally pellucid. Some fine smoky quartz has been found at Goshen, Massachusetts, and by Mr. Gideon Bearce at Minot, Maine. A mass of fine clear smoky quartz weighing over 6 pounds, with clear spaces several inches across, was found in the summer of 1884 on Blueberry hill, Stoneham, Maine; and a fine crystal over 4 inches long and 2 across, very clear in parts, was found near Mount Pleasant, Oxford county. Dr. Genth(*b*) mentioned smoky quartz near Philadelphia; on the Schuylkill, near Reading, Berks

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a "Mineralogy of Nevada."

b "Preliminary report on the Mineralogy of Pennsylvania," page 58.

county; near Hammerstown, Dauphin county; in Upper Derby, near Garret's road tollgate, and near the Kellyville schoolhouse, all in Delaware county; also at the tunnel near Phœnixville, and in East Nottingham and Birmingham townships, Chester county. In certain parts of Delaware and Chester counties the amethyst and smoky quartz gradually shade into each other, a characteristic peculiar also to many from the North Carolina localities. Alexander, Burke, and Catawba counties and other localities afford fine smoky quartz crystals. Some very fine ones have been found at Iron Mountain, Missouri.

From a region 20 miles west of Hot Springs, for about 60 miles westward, the quartz crystals as a rule are all doubly terminated and detached, and are found loose in the sand between the breaks or veins in the sandstone, which somewhat resembles the calciferous sandstones of Herkimer, New York. At that part of this region called "the gem country," nearest Hot Springs, the crystals are quite white, but gradually shade into a dark smoky color at the other end of the district. As a rule all the quartz is filled with fluid cavities. Some four hundred crystals with liquid inclusions were obtained from two veins of sand within three days.

Most of the cut articles of smoky quartz sold at the tourist localities are of foreign material cut abroad at a very low figure. Smoky quartz pebbles are rarely found in the sands along our coasts. At the watering places, such as Long Branch and Cape May, they are, however, occasionally found and cut as souvenirs.

The Pike's peak region at Bear creek is by far the richest locality for smoky quartz, and many thousands of crystals have been procured from 1 inch to those from 1 foot to over 4 feet long.(*a*) Considerable of this material has been sent abroad for cutting. Crystals are also found on Elk creek and the Upper Platte. Smoky quartz is found near Placerville, El Dorado county, California, in the placers. A fine large crystal 6 inches in diameter was in the cabinet of Dr. White, of Placerville.

A specimen of the rose quartz from Stow, Maine, cut into a long double cabochon from a massive transparent piece of quartz, distinctly shows the asteria effect similar to the star sapphire, if viewed by sunlight or artificial light.

Aventurine(*b*) quartz has not been observed from any American locality in fine specimens, although mentioned by Dr. F. M. Endlich as occurring on Elk creek, Colorado. Prof. John Collett has lately found a few small specimens of white aventurine quartz pebbles in the drift near Indianapolis.

Rose quartz.—At Stow, Albany, Paris, and a number of other localities in Maine, the veins of quartz shade from white, transparent, and opalescent resembling hyaline quartz, often without any imperfections, through faintly tinted pink and slightly salmon colored, into a rich rose

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a Dr. A. E. Foot's cabinet.

b Tenth Annual Report, F. V. Hayden, Geological Survey, 1876, page 150.

color, thus forming a beautiful series of tints of color that have merit for a common gem or for ornamental stone work. Possibly as fine transparent opalescent rose quartzes as have ever been found were recently obtained, in pieces free from all flaws, of a fine rose-red with a beautiful milky opalescence 4 by 5 inches in size, at Round mountain, Albany, Maine. A beautiful opalescent quartz has been found at Daw river, Stokes county, North Carolina. Rose quartz is found at many localities in the granites of Colorado, also in fine specimens at the head of Roaring fork, from near Clear creek, and on Bear creek. It is mentioned by Hoffmann, from Tuscarora, Moray, and Carlin, and Silver Peak, Nevada(*a*); also by Sweet(*b*) in crystals from Grand Rapids, Wood county, Wisconsin.

Prase.—Prase is found always crystallized at the various limonite deposits on Staten Island, New York. As specimens the mineral is very good indeed; groups of crystals are often 8 or 10 inches across, although the crystals are rarely over one-half inch long and one-eighth inch in diameter. The color as a rule is a dark leek green of no gem value.

Prof. W. P. Blake(*c*) mentions a greenish-tinged quartz resembling datolite in color, from the French lode, Eureka district, California.

Hoffmann, in the "Mineralogy of Nevada," mentions prase in crystals at Reese river, San Antonio, and occasionally on the mountain near Silver Peak.

A translucent leek-green variety(*d*) of chalcedony and quartz occurs in the syenitic range of the Lehigh, especially at the allanite locality, 5 miles east of Bethlehem, Pennsylvania. Prase is found at Blue hill, Delaware county, in doubly-terminated crystals, in curious crossings and rosettes several inches across; also in inferior specimens near Dismal run, Delaware county. Very fine quartz(*e*) occurs in its massive variety at George Van Arsdale's quarry, Bucks county; in Delaware county at Radnor; and in East Bradford township, Chester county.

Quartz inclusions.—The quartz inclusions as they occur in some varieties are sometimes of great beauty, and constitute an important part of the American gem minerals. As some of these are quite rare and little known among collectors, mention of a few of the leading American localities may not come amiss.(*f*)

Two of the finest known specimens of rutilated quartz are of American origin; they are massive smoky quartz, evidently parts of one crystal. One of them was originally in the possession of the late Dr. Chilton(*g*) as early as 1847, and is now in the Vaux cabinet at the Philadelphia Academy of Sciences. It is about 7 by 3½ inches, and is

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a "Mineralogy of Nevada."

b Sweet's "Minerals of Wisconsin."

c "Catalogue of Minerals of California," 1866, page 20.

d Preliminary report on the Mineralogy of Pennsylvania, page 59.

e Preliminary report on the Mineralogy of Pennsylvania, page 58.

f See also paragraphs on rutile, amethyst, and garnet.

g "Proceedings American Association for the Advancement of Science," 1849.

completely filled with transparent essonite-red crystals of rutile, some of which are over 6 inches long and from the thickness of a knitting needle to that of a thin lead pencil; the larger crystals are slightly flattened. The other belongs to Prof. Oliver P. Hubbard(*a*), of Dartsmouth College, and is 7 inches long by 3 inches across, and of a rich smoky color. The included crystals are a fine essonite-red, but not thicker than a knitting needle. Both were brought from some Vermont locality now unknown; believed, however, not to be Bethel or Rochester, notwithstanding these localities have furnished many fine crystals of similar size filled with beautiful rutile. Beautiful pieces of quartz 3 by 4 inches, and fine crystals of quartz penetrated by beautiful clove-brown and black rutile, were formerly found at Middlesex, Vermont.

Rutilated quartz of unexcelled beauty, the rutile usually brown, red, golden, and black, has been found at many localities in Randolph, Catawba, Burke, Iredell, and Alexander counties, North Carolina; and during the last year, at the emerald mine at Stony Point, crystals of quartz have been found 3 inches in length, and filled with rutile as thick as a knitting needle. Fine pieces of quartz 4 inches square, containing acicular rutile of a rich red color, were found near Amelia Court-House, Virginia. Some fine acicular crystals of rutile in limpid quartz, in the possession of Mr. Joseph Wharton, were found near Knitzer's, Lancaster county, Pennsylvania.

Mr. Samuel R. Carter has in his cabinet cut specimens of pieces of bluish quartz filled with small acicular crystals of indicolite, somewhat resembling rutile in quartz, with the exception of the blue color. These were found in pieces over 1 inch square at the famous tourmaline locality at Mount Mica, Paris, Maine.

The mining operations at Stony Point, North Carolina, brought to light a number of crystals of quartz, some 4 inches long and 3 inches across. Large pieces of quartz 3 inches square, filled with what appears to be asbestus or byssolite, form interesting and pretty specimens. The inclosures of what appears to be göthite in red fan-shape crystals from North Carolina also form very pretty and interesting gem stones.

A fine limpid crystal(*b*) of quartz, 1 inch long and two-thirds of an inch in diameter, penetrated by fine green crystals of actinolite one-half millimeter in diameter, is said to have been found at some Virginia locality. The so-called Gibsonville emerald(*c*), exactly similar to the above, the crystal being 3 by 2 inches, was plowed up in a field at Gibsonville, North Carolina.

Some crystals of limpid quartz have been found in California containing particles of native gold; one of these was said to be 1 inch long, and inclosed a scale of gold about the size of the end of a finger

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a "Proceedings American Association for the Advancement of Science," 1849.

b Cabinet of Tiffany & Co.

c See page 725.

nail. Two of these inclusions, not so large, are in the possession of Rev. W. C. Hovey, of Minneapolis, Minnesota.

In Nevada county, California, in the Grass Valley mines, quartz is often found supporting gold between the crystals. Pellucid crystals of quartz, some 1 inch long and three-fourths of an inch across, filled with a very brilliant stibnite projecting in all directions and some of them curiously bent, were found at the Little Dora mine, Animas forks, San Juan, Colorado, Mr. John W. Palmer, of Chicago, owning a very fine one. This material is capable of being made into one of the finest of this class of gems that have been found at any locality.

The beautiful specimens of limpid milky quartz, and also quartz crystals, the latter at times from three-fourths of an inch to 2 inches long, are found penetrated by crystals of black hornblende varying in size from acicular to those one-sixteenth inch in diameter and at times 6 inches long. They interlace and penetrate the quartz in every direction, making a very beautiful gem and ornamental stone. Fine pieces 6 inches square have been found. It occurs at the quarry at Calumet hill, Cumberland, Rhode Island, where the workmen, as a rule, knowing its value, secure the best specimens for disposal to the greatest advantage. Some hundreds of pounds of this material were sent abroad a few years ago to be cut up for jewelry at Idar and Oberstein. As, however, work has been suspended at the locality, the mineral is likely to become somewhat uncommon. Cut specimens sell at from 50 cents to $5, and specimens polished on one side at from 25 cents to $5. This locality is one of the best known for this association.

Among other inclusions that might be utilized for gems may be mentioned the following: Crystals of quartz filled with specular iron found at the Sterling mine, Antwerp, New York; quartz including scales of hematite from King's Mills, Iredell county, North Carolina; dolomite in pellucid quartz of Herkimer county, New York; crystals of quartz containing crystals of the green spodumene (hiddenite) from Stony Point, North Carolina, and fine inclosures of chlorite and mica, green when viewed through the side of the prism, from several North Carolina localities.

The corals and sponges of Tampa bay, Florida, which are so often found there altered to chalcedony by the sileceous waters, are at times filled with fluid that was imprisoned while the regular deposition of silica closed the apertures that admitted the siliceous water. These, as well as the ones found in Uruguay, the so-called hydrolites, or waterstones, are always lined with drusy quartz. If not as beautiful as those from Uruguay, they are even more interesting, and have been sold at from $2 to $20 each.

The crystals of quartz from the Herkimer (New York), North Carolina, and Arkansas localities, containing fluid cavities with moving bubbles, are at times cut into ornaments which are not only interesting but pretty. One of these pure limpid crystals with a crescent-shaped cavity, from Little Falls, was mounted in a pair of gold ice-tongs to represent a cake of ice. These crystals are valued at from $1 to $25 each. In Rabun county, Georgia, the fine amethysts often contain these cavities nearly 1 inch long, and would afford good gems, as would also those from Stow, Maine.

The quartz pseudomorphs, after calcite cleavages, from the locality 2 or 3 miles northwest from Rutherfordtown, Rutherford county, North Carolina, at times contain liquid in irregular-shaped cavities, and from their breaking out in good shape can be utilized for curious ornaments. This variety of quartz was also found by Mr. J. A. D. Stephenson in Iredell county. Possibly the finest specimen is one belonging to Mr. W. B. Dinsmore, of New York City. It is about 1 inch long and the surface is coated with a beautiful bluish white chalcedony with a curious rough surface, and it is perfect on all sides, with a free movement of the bubble. It is so thin and so filled with liquid that the liquid would weigh fully twice as much as the quartz walls. It is of the proper size and sufficiently beautiful for personal ornament. As nearly as can be ascertained it is from some locality in Georgia.

In the cabinet of Dr. Isaac Lea, of Philadelphia, there are perhaps thousands of remarkably fine and unique inclusions in quartz, as well as in all known gems, probably, in fact, every known form of mineral inclusion, forming undoubtedly the finest cabinet of "included minerals" in the world, the result of scores of years of keen observation and careful microscopic work. In the cabinet there are, of course, many stones which could be cut into fine gem stones, but which possess a higher interest as mineralogical specimens.

Agate and chalcedony.—The "trap" along the Connecticut river, especially at Amherst and Conway, Massachusetts, and Farmington, East Haven, Woodbury, and Guilford, Connecticut, affords agates of considerable beauty, though rarely over 3 inches across. The so-called chalcedonic balls of Torringford are very handsome when polished, and the rich carnelian shades with milky translucency afford a pleasing contrast. Many of these were cut into the form of sealstones as early as 1837(*a*), which were fully equal to any from abroad in the delicate arrangement of the layers and the richness of the colors. At Natural Bridge, Jefferson county, New York, fine agates have been found. The Belmont lead mine, Saint Lawrence county, has afforded some very good chalcedony. White, yellow, and blue chalcedony of good size was found 4 miles east of Warwick, at Bellvale, Orange county, New York, by Dr. W. Horton.(*b*)

Chalcedony is found in Delaware county, Pennsylvania, principally at Middletown and Marple. Brown botryoidal masses occur at the Hopewell mine; also, at Williston, West Nottingham, West Goshen, and London Grove townships, in Chester county; a pale blue variety at

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a C. U. Shepard: "Mineralogical Report of Connecticut," 1837.

b "Geological Survey of New York," 1840; Report on Orange county minerals.

Cornwall, Lebanon county; near Rock spring and Wood's mine, in Lancaster county; between Clay and Hamburg; also, at Flint hill, Berks county; in Cherry valley, Munroe county; at Conshohocken, Montgomery county, and at other localities in Pennsylvania. From many of these localities, especially in Delaware and Chester counties, ringstones, sealstones, and other ornaments are worn by the residents who have had them cut from local material.

Agates are found abundantly on the entire Lake Superior shore, and along the Mississippi river, especially in Minnesota, and fine chalcedony occurs 5 miles north of Grand Rapids, Wisconsin. Agate and chalcedony are both found at the Fox river, Illinois. Agate, chalcedony, and carnelian are found near Van Horn's well, Texas, and near Hot Springs, Arkansas.

The agates of the Yellowstone National Park and Holbrook, Arizona, equal any yet found.

A rich fawn and salmon colored chalcedony has been found in Burke county, North Carolina, by E. A. Hutchins. At Caldwell's, Mecklenburg county; near Harrisburg and Concord, Cabarrus county, and Granville, Orange county, and in other localities in North Carolina, fine agates and chalcedony have been found.

In Colorado chalcedony is found 8 miles south of Cheyenne mountain at the Los Pinos agency at Chalk Hills; on the bluffs near Wagon-Wheel Gap and along the upper Rio Grande valley; in Middle and South parks, Buffalo park, Fair Play, Frying Pan, Trout creek, Gunnison river, and frequently in drift accumulations.

Agate is found in fine specimens lined with amethyst on the summit of the range of the Animas, clouded white and gray in the lower trachytic formations of the Uncompahgre group. It occurs in a variety of forms, clouded, banded, laminated, and in a variegated form, at the Los Pinos agency; also in the South park in the drift, in the lower Arkansas valley, on the Frying Pan, and throughout the Middle park in the form of onyx and sardonyx, on the lower Gunnison and adjacent regions.

Prof. W. P. Blake (*a*) mentions large masses of white chalcedony, delicately veined and in mammillary sheets, near the Panoches, in Monterey county, California; on Walker river, Nevada; also of a fine pink color near Aurora, Esmeralda county, Nevada; and in pear-shaped nodules in the eruptive rocks between Williamson's Park and Johnson's river, Los Angeles county, California.

Beautiful pebbles of agate and chalcedony are abundant along the beach of Crescent City, California, and are often cut as souvenirs; they are usually of a light color. In the pebbly drift of the Colorado river they are more highly colored, more abundant, and of larger size; many of the surf-worn pebbles of the Pescadero beach, California, are agate and quartz, of very fine bright colors; occasionally these are

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a "Minerals of California," page 9, 1866.

utilized as gem stones. Fine agates and jaspers are found about the Willamette, Columbia, and other rivers in Oregon. Beautiful red and yellow carnelian and sardonyx result from the silicification of the corals and sponges at Tampa bay, Florida, and although the pieces are not large, the colors being natural are very good.

The silicified bones of the atlantasaurus found at Morrison, Colorado, have at times a coarse cellular structure, infiltrated with carnelian, giving a very pleasant effect of a brilliant red striped and mottled appearance.

Chalcedony coats and incloses the crystallized cinnabar of the Redington and other mines of California; and these crusts, if cut with the cinnabar, form very pretty and interesting gem stones.

Silicified coral.—The true silicified corals found at Schoharie, New York, along the Catskills, and at a large number of other American localities, form very pretty gem stones. Some similar to the so-called fossil palm wood from India have been observed at a few localities in New York State. One very interesting black siliceous coral form with large white markings was found at Catskill, New York; when cut across the large white columnar lines the effect was very pleasing and ornamental.

Silicified wood.—In the valley of the east fork of the Yellowstone river, and in the volcanic Tertiary rock, which here attains a thickness of 5,000 feet and is made up of fragmentary volcanic products which have apparently been redistributed by water and now form breccias, conglomerates, and sandstones, Mr. W. H. Holmes(*a*) mentions the occurrence of silicified wood in great abundance, and in some cases the trunks are *in situ* in these strata.

In the valley of the main Yellowstone, in the Gallatin range, and about the sources of Cañon and Boulder creeks, also near the divide at the head of Boulder creek, and at a number of points above this line, may be observed trunks many feet in height and of gigantic proportions, standing in the identical strata in which they grew. In general, these strata are horizontal. Three miles south of Gardiner's river, at an elevation of 6,000 feet above the sea, silicified trunks are found in sandstone belonging to the same strata. On the south side of Third cañon, opposite the mouth of Hell-roaring creek, is a massive promontory, in which many fine trunks are exposed in a conglomerate. At Amethyst or Specimen mountain some of these trunks have been found 10 feet in diameter. Many thousands of silicified trees are found; in some cases the structure is well preserved, and in other cases completely agatized or opalized, and lined with crystals of calcite, quartz, and beautiful amethysts. In this locality many of the finest specimens of American silicified wood are found.

The workmen on the Denver and New Orleans railroad in 1882(*b*),

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a "Geology of the Yellowstone National Park," page 48.

b A. E. Foote, *Naturalist's Leisure Hour*, July, 1882, page 32.

while within 20 to 30 miles of Denver, Colorado, between Cherry and Running creeks, were met by an obstacle in the form of a buried forest. The trees are of various sizes, all silicified and agatized, and buried at depths of from 10 to 20 feet; they are very perfect and are met with in a half dozen localities.

Numerous newspaper articles have appeared on the utilizing of the petrified forests near Holbrook, Arizona, by a company which is making large ornaments of the material, and which have gradually driven the so-called California and Mexican onyx out of the market. A company has been formed, however, and a large exhibition of this material was made at New Orleans, and a quantity of the mineral was sold, usually as small paper weights or for small jewelry ornaments. The company has been reorganized, and with its new sawing machinery hopes to be able to cut table-tops, tiles, and for other like purposes. The material is one of the finest known for color and hardness that could be used in this way. A stump, 18 inches across and 3 feet high, was sold to a Russian at New Orleans. Immense quantities of the material exist in Arizona and in magnificent specimens. One in the Peabody museum is fully 24 inches across and very compact; some of the trunks are at times magnificently lined with quartz and amethyst. One tree, fully 100 feet long, spanning a chasm and making a natural bridge, is one of the attractions. Some use may arise for the material if cheap polishing and slitting can be introduced, and no doubt in the near future some developments will be made in this line, since a second company has obtained property adjoining that of the company doing the work. The cutting of some sections of a 12-inch trunk into bottoms for solid silver trays is one of the novelties introduced by a leading jewelry firm.

Moss agate.—Moss agate was formerly found near Hillsborough, Orange county, North Carolina. The agatized trees from Holbrook and Specimen mount show these mosslike markings more like the fine tree-stones from Brazil than our common American agate. One curious stalactite of chalcedony, about 3 inches long and having the appearance of a piece of common sperm candle, had a black core through its entire length about the size of a candle wick, making it at first sight scarcely distinguishable from a half-used candle. It was unfortunately cut into a number of matched stones for cuff-buttons, which were very unique with the beautiful black central dot.

In the southeastern part of Humboldt county, Nevada, are large quantities of moss agate of the dendritic and "fortification" forms, which, however, have been utilized to a very limited extent.

Moss agate has been very sparingly used during the past year, the sales amounting to not over $1,000. Since the recent introduction into cheap jewelry of the Chinese natural green and artificially-colored red and yellow moss agate, the sale of the American has almost entirely fallen off. A so-called moss agate is found at Rock Springs, Lancaster county, Pennsylvania, and also near Reading, Berks county. A beautiful moss jasper is found in Trego county, Kansas.

Chrysoprase.—Possibly the best American chrysoprase was found within the last year by Mr. F. E. Monteverde, at Nickel mountain, near the town of Riddle, Douglas county, Oregon. The chrysoprase was observed in small veins about one-eighth inch thick, and furnished a number of flat stones of a rich green color, that were over 1 inch square; it occurs in a vein of serpentine associated with the nickel ores.

Traill(*a*) mentions chrysoprase from New Fane, Vermont, which mineral Prof. J. D. Dana refers to green quartz and not chrysoprase, although it was also so-called at the locality where found.

A fine green-colored specimen intermixed with a black hornblende that would afford gems 1 inch across was shown to me by Mr. E. A. Hutchins, of New York, and was found at some locality in Macon county, North Carolina.

Mr. Thomas A. Tabor, in 1839, mentions in a letter to Dr. C. A. Lee the occurrence of chrysoprase in Chester county, Pennsylvania, without any description of its quality, though one would infer that it was of gem quality, since Mr. Tabor was a jeweler. Dr. F. M. Endlich(*b*) mentions chrysoprase as of rare occurrence in Middle park, Colorado.

Opal.—Beautiful fire opal without any opalescence is found in Washington county, Georgia, and was first described by Prof. G. J. Brush, who has the finest piece in his cabinet. It is a vein about one-fourth inch thick and 2 inches square.

Common opal occurs rarely in small masses of a greenish and yellowish white with vitreous luster, at Cornwall, Lebanon county, Pennsylvania. It is found at Aguas Calientes, Gilson gulch, at Idaho Springs, Colorado, in narrow seams in the granite, and most of it is brownish. Mr. J. W. Beath states that he had seen fine opal specimens showing play of colors, said to have come from the Idaho Springs locality. At Colorado Springs it occurs milk white in color.

The following is communicated by Mr. C. G. Yale: "While the precious opal has never been found in the Pacific division, the common kind occurs in numerous localities. Large and very beautiful opalized wood is frequently found in the hydraulic mines of California. Small stones in great number are also taken out of some of the drift mines. A few of these being infiltered with the oxide of manganese, giving them the appearance of being filled with moss or possessing other peculiarites, are enough sought after to give them some little value."

Hoffmann(*c*) mentions opal in magnificent colors (evidently opalized wood) with silicified wood, and states that on breaking some of the large trunks at San Antonio, Nevada, fine specimens were obtained.

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a "Quartz and Opal," page 35.

b "Catalogue of Minerals found in Colorado," 1876; tenth annual report of the Hayden Survey, page 150.

c "Mineralogy of Nevada."

Hyalite occurs with cachalong at several localities in Yavapai county, Arizona; at the Philips ore bed, Putnam county, New York; and cachalong at Bellevale, 4 miles east of Warwick; in Burke and Scriven counties, North Carolina; in yellow fluorescent coatings upon gneiss at Frankford, Pennsylvania, and at Avondale, Delaware county, in bluish-green; also at Megarge's paper mill on the Wissahickon. Hyalite occurs at Concord, Cabarrus county, and the Culsagee mine, Macon county, North Carolina. Associated with semi-opal it is mentioned in the Mount Diablo range about 30 miles south of Mount Diablo.

Prof. W. B. Blake(*a*) mentions that a rich white variety of opal is found at Mokelumne Hill, Calaveras county, California, or on the hill near that place known as Stockton hill, on the west side of Chile gulch. A shaft had been sunk 345 feet, and the opals were found in a thin stratum of red gravel. They varied in size from that of a kernel of corn to a walnut, many of them containing dendritic infiltrations of oxide of manganese resembling moss. In 1866 about a bushel of these stones were raised in a day, and were reported to have a market value. A milky variety similar to the above, and without fire, is found with the magnesite on Mount Diablo, 30 miles south of the mountain; also in the foot hills of the Sierra at the Four creeks.

Beautiful pieces of a moss-marked opal, similar to moss agate, are found in Trego county, Kansas. They are often 3 and 4 inches across.

Semi-opal is found together with the chalcedonies at the Los Pinos agency, and north of Saguache creek, Colorado, in trachyte.

Geyserite.—Some of the geyserite from the geysers in Yellowstone park, especially at Firehole river, occurring in such a variety of concretionary and imitative forms, might be used for small ornaments.

Jasper.—Dr. Genth mentions that cat's-eye has been observed in several localities; a fair hexagonal crystal with the pyramid of greenish color, resulting from very fine fibers of actinolite disseminated through it, came from York county, Pennsylvania; it is found also 5 miles east of Bethlehem at the allanite locality, but not of gem quality.

A curious dark-gray piece of quartz was observed from the West Shore railroad tunnel at Weehawken, New Jersey(*b*), that was filled with what seemed to be byssolite, but really may be an altered pectolite, and would cut a tolerably fair mineralogical cat's-eye.

The so-called Thetis hairstone described by Dr. Jackson(*c*), found at Cumberland, Rhode Island, is really a quartz cat's-eye, and some very fair cat's-eyes have recently been cut from it by Mr. Edwin Passmore, one of them nearly two-thirds of an inch long, and quite equal to many from Hoff, Bavaria.

Little or no novaculite has been used during the last year for ornamental purposes, although it has some use as streakstones for miner-

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a "Catalogue of California Minerals," 1866, page 18.

b Cabinet of G. F. Kunz.

c "Geology of Rhode Island," 1839.

alogical work, being better adapted for this purpose than anything else, owing to its hardness and pure white background.

Red jasper is found on Sugar Loaf mountain, Maine, and a fine yellow with chalcedony has been found at Chester, Massachusetts; fine red and yellow also by Dr. Horton 4 miles east of Warwick, at Bellvale, Orange county, New York; pebbles of fine red occur along the Hudson river from Troy to New York, especially at Hoboken, Fort Lee, and Troy, where the jaspery rock outcrops. The so-called green jasper of Norman's Kill from the Hudson river slates was used by the Indians for arrow points.

Jasper agate is found in considerable quantity at Diamond Hill, Cumberland, Rhode Island, in all shades of white, yellow, red, and green; these colors are also all intermixed in one specimen, usually mottled, and at times beautifully banded in irregular seams of white, creamy brown, greenish, and brecciated. It is found in large quantities, and although fully 1,000 pounds is taken away every year by visitors and collectors, not over $100 worth is sold or polished per annum.

Large pieces of fine yellow jasper have been found at Tyringham, Massachusetts, by Mr. Daniel Clark, of that place.

In Pennsylvania(*a*) jaspers more or less impure are abundant in the drift of the Delaware and Schuylkill rivers; also in Berks county, near Reading. Brownish-yellow is found at West Goshen, Chester county, and a reddish brown variety near Texas, Lancaster county, and a brown banded variety at the hydropathic establishment near Bethlehem. The arrow heads found in this vicinity and near Easton are mostly made of jasper. The jaspery sandstone so plenty near Mauch Chunk might be utilized for large ornamental work with advantage.

In North Carolina fine jasper, banded red and black, is found in Granville, Person county; bright brick-red and yellow at Knapp's, Reed's Creek, Madison county; at Warm Springs; at Shut-in Creek in Moore county; also in Wake county, and elsewhere in the State.

In Texas fine jasper has been found near Fort Davis, Bexar county, and at Barilla Springs, where are found the jaspery agates called Texas agate.

The moss jasper of Trego county, Kansas, is equal to any yet found.

Fine-yellow, brown, and red jasper is found at the Los Pinos agency; throughout the Middle and South parks; along the Gunnison, in the Dakota group; on the Arkansas, Grand, White, Animas, and other rivers of Colorado, in the drift, and in some of the trachytes, mostly red, green, and brown. A very fine specimen was found at the junction of Lost Trail creek and the Rio Grande. Small but smoothly worn pebbles of jasper and agate are quite plenty on the shores of Lake Tahoe, California. Red and green jasper are very abundant in the

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[a] "Preliminary report on the Mineralogy of Pennsylvania," page 60.

neighborhood of San Francisco, though not of fine quality; some of this stone has been used in building and for sidewalks.

Fine red jasper is found on the Little Colorado river, New Mexico, and also on the Willamette, Oregon. The latter region evidently furnished the material for the fine arrow points of Oregon.

The banded jasper found near Colyer, Graham county, Kansas, red, yellow, and other colors, with even white bands, affords blocks over 1 foot long and 6 to 8 inches wide, and really merits the attention of workers in ornamental stone, as it is unrivaled in the world for banded jasper.

Bloodstones in beautiful specimens with the red markings very fine are found at Chatham county, Georgia. Some fine heliotropes from here are in the cabinet of W. W. Jefferis. Heliotrope was formerly found in veins in slate at Blooming Grove, Orange county, New York. Some very fine pieces have been found near the Willamette river, Oregon, and of fine quality near the South park, Colorado, and below the Uncompahgre, near Grand river.

Basanite was found by Dr. Horton(*a*) at Canterbury and Cornwall, New York. It is also sparingly found in nearly all the drift north of New York City, and in that of the Delaware river from Easton, Pennsylvania, down to the State line.

Gold quartz.—The gold found in California quartz is worth about $16.50 per ounce, but jewelers will give willingly from $20 to $30 for each ounce of gold contained in such material as they can use. The price of specimens varies according to their beauty from $3 to $40 per ounce of quartz. The specific gravity of the mineral is taken, after which the gold value is ascertained by a table called Price's table. The amount of this material in the rough sold for jewelers' purposes is variously estimated at from $40,000 to $50,000 per annum, $1,000 to $2,000 worth being often purchased at one time. One lapidary at Oakland, who employs several assistants, purchased nearly $10,000 worth within one year, and a large jewelry firm in San Francisco, during the same time, purchased nearly $15,000 worth of this material.

Great care must be taken in the selection of the quartz. The stone used must be large enough to bear the rough treatment of the diamond saw and the lap wheel of the polisher; all of the ore is friable, and some of it crumbles to pieces while undergoing these processes. For the same reason all the pieces set in cabinet work are small; the saw hanging in the gold in the slitting prevents the cutting of large pieces, as the wafer-like slabs are apt to be broken by this resistance while being separated from the block. Pieces 4 by 2 inches are quite rare, although fine pieces 4 inches square are at times seen.

Rarely more than one-half of the ore purchased finds its way into the mounting owing to this breakage and the trimming into shape. Nearly all the cutting of this material is done at Oakland, California.

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a "Geological Survey of New York," 1840.

The white gold quartz of California is mainly supplied from the following counties: Butte, Calaveras, El Dorado, Mariposa, Nevada, Placer, Sierra, Tuolumne, and Yuba.

The black gold quartz, a quite recent novelty, is found at the Sheep Ranch mine, Calaveras county, and at Sutter creek, Amador county, California.

The so-called rose gold quartz is made by backing a translucent quartz with the desired shade of carmine paste, and forms an effective contrast to the opaque white and black gold quartz with which it is usually mounted in some design.

Single stones for scarf pins, rings, and sets of pin and earrings, sell from $2 to $10 each, and occasionally exceptionally fine or curious pieces bring higher prices.

It is not many years since gold quartz has been utilized to any great extent in jewelry. At first the designs were usually simple and the mountings very modest, but the demand has created a supply of the most elaborate designs, and at present it is used in every conceivable form of jewelry, and in articles of personal or house adornment of almost unlimited variety, such as canes, paper weights, writing cases, perfume bottles, fan sticks, bracelets, watch chains, and lace pins, the latter in such designs as shovels, picks, and other mining emblems.

In certain kinds of furniture it is used as paneling; and here, as in the jewelry, the effect is better brought out by added colors, such as are afforded by agate, moss agate, silver rock, smoky quartz, pyrite, chalcopyrite, cinnabar, malachite, turquois in the matrix, and other bright minerals.

Much of the jewelry made of this material is sold to tourists from the eastern States and from other countries. Eleven hundred dollars' worth was recently purchased by an Asiatic embassy, and scarcely any one visiting California fails to purchase a memento. The sale is increasing.

The best taste as a rule is not exercised in the designs. Many are too large and ungainly for personal adornment, and many others are not as well mounted as most of the other jewelry sold with them. Perhaps not one article in ten sold will have much if any wear. There is much room for improvement in the line of this work.

One of the large designs made of gold quartz, representing the cathedral of Notre Dame, at Paris, is valued at $20,000. It stands about 12 inches high, and is perhaps the finest piece of gold quartz work produced.

A mass of gold quartz(*a*) weighing 160 pounds was hydraulicked out of the bank of the Nevada Hydraulic Company at Gibsonville. The bowlder was smoothly washed and had the appearance of having been ground in a pothole. Its estimated value was $2,500, but its real worth was more, since it was valuable for lapidaries' purposes.

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a Jewelers' Circular, Vol. XIV., page 258, September, 1883.

It is stated that some years since a Mr. Thiery devised a method of fusing quartz and throwing in lumps of heavily alloyed gold, and allowing the material to cool in molds of required shapes. It is said the mingling of the metal and the quartz was complete, but the quartz had a milky, unnatural glasslike appearance entirely unlike the gold quartz it was intended to represent. Messrs. LeDuc, Connor & Laine, on applying for a patent for an imitation gold quartz produced by means of electricity, found that a similar patent had been issued nearly fifty years ago to a New York man. However, notwithstanding they were not able to obtain the monopoly, they started as manufacturers of jewelers' quartz, but abandoned it, as it proved so unsatisfactory.

Actinolite.—The emerald-green glassy actinolite of Concord township, Pennsylvania, is very fine and might be utilized in some form, possibly the compact, as a form of cat's-eye. An inlaid ornament of this mineral taken from an old piece of furniture in London during the early cat's-eye excitement netted the persons who cut it up hundreds of dollars.

Rutile.—The rutile of Middletown, Connecticut, was cut into gems that were almost ruby in color, as early as 1836, by Prof. C. U. Shepard.

The finest small brilliant geniculated crystals are found at Millholland's Mills, White Plains, at John Lackey's farm, near Liberty Church, and at Wilson's near Poplar Springs, in Alexander county, North Carolina. These have furnished some of the finest cut black rutile, which more closely approaches the black diamond in appearance than any other known gem. Some of the lighter colored ones furnished gems closely resembling common garnet.

Beautiful long crystals, at times transparent red, have been found, ranging in thickness from that of a hair to one-quarter and in some few cases nearly two-thirds of an inch across, and from 1 to 6 inches in length, at Taylorsville and vicinity, and at Stony Point, North Carolina. These are very brilliant and at times doubly terminated.

Beautiful crystals are also found in quartz and loose in the soil at Sadsbury township, Pennsylvania, for 7 miles along the valley, especially near Parksburg, where double geniculations and geniculations forming complete circles are found, weighing over 1 pound. This is the "money stone," so called by the inhabitants of the district, as it is often looked for because they can obtain money for it from the collectors; some of the finer small ones are worn as ornaments.

Some of the beautiful geniculated nigrine from Magnet cove would also well serve the purpose of ornament. These and the Alexander county rutiles are possibly the finest in the world.

Axinite has been observed with the essonite and idocrase at Phippsburg and Wales, Maine, and also at Cold Spring, New York. The best American locality is the one near Bethlehem, Pennsylvania, first found by Prof. F. Prime, jr., and Dr. Reopper, and described by Prof. B. W. Frazier.(*a*) These crystals, colorless, pale yellowish, and brown, are

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a American Journal of Science, December, 1882.

at times one-fourth inch long, and future finds in this vicinity may bring some gems to light; up to this time no stones suitable for fine cutting have been found, though a few might furnish mineralogical gems.

Jade.—Among the implements collected by the Point Barrow (Alaska) Expedition were a number made of dark green jade. This mineral is supposed to be found in a place somewhere to the east of Point Barrow.

Rhodonite.—Rhodonite has been found in an extensive bed at Blue Hill bay, Maine, on Osgood's farm; also in bowlders at Cummington, Massachusetts, and in the neighboring towns; at Warwick, Massachusetts; in Irasburgh and Coventry, Vermont; near Winchester and Hinsdale, New Hampshire; and at Cumberland, Rhode Island.

The Alice mine, at Butte City, Montana, has produced a large quantity of rhodonite associated with rhodocrosite, and it has here been used to some extent as a gem stone.

It has recently been described by Mr. William North Rice(*a*) as occurring at the White Rocks, Middletown, Connecticut—only in a limited quantity, however.

The variety fowlerite, found at Franklin, Hamburg, and Sterling, New Jersey, is also very fine in color.

Rhodonite has recently been used very effectively in combination with unpolished or stone-finished silver, as handles for very fine ornaments, the rose color streaked with black presenting a very pleasing contrast.

Epidote.—Fine crystals of epidote have been found at Haddam, Connecticut, which might yield small gems. The large crystals in quartz at Warren, New Hampshire, were all too opaque, though fine as cabinet specimens.

At Roseville, in Byram township, Sussex county, New Jersey, epidote was formerly found in good crystals that would afford mineralogical gems.

Dr. F. A. Genth(*b*) mentions a crystal of epidote in the cabinet of the University of Pennsylvania, from the gold washings of Rutherford county, North Carolina. This crystal is strongly pleochroic, like the so-called puschkinite from the auriferous sands of Katherinenburg, in the Ural mountains, and would cut the best American gem yet found.

Some fine highly complex forms have been observed at Hampton's, Yancey county, North Carolina, by Mr. William Earl Hidden.(*c*) The Yancey county crystals would also possibly afford cabinet gems, none of them as fine, however, as the Tyrolese epidote.

In Chester county, Pennsylvania, crystals 3 inches in length have been found. The principal localities are the Smith and McMullin farms, West Bradford township; East Bradford, where dark green specimens

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[a] *Science*, Vol. I., No. 21, page 601.

[b] "Minerals and Mineral Localities of North Carolina," 1881, page 44.

[c] *Ibid.*, page 86.

occur, and Taylor's mill, West Goshen. In East Marlboro' township it occurs in yellowish-green crystals, and at McCloud's farm and Pearce's old mill, Kennett township. In the limestone quarries of London Grove and Sadsbury townships it occurs in bottle-green crystals.

Idocrase.—Idocrase or vesuvianite that would yield small gems has been found at Phippsburg, Maine.(*a*) A beautiful wine-colored variety(*b*) is mentioned as occurring near New Hope, Bucks county, Pennsylvania.

At the locality 1½ miles from Sanford, Maine, idocrase occurs in unlimited quantities, one ledge being fully 30 feet wide, made up almost entirely of this mineral associated with quartz and occasionally with calcite. Some of the crystals are 7 inches long, and the smaller ones would afford fair gems at times.

Idocrase is mentioned by Endlich as occurring in large crystals on Mount Italia, Colorado, and north of the Arkansas river, in granite.

Cassiterite.—The finer crystals of cassiterite found at Hebron, Norway, and Paris, Maine, would afford mineralogical gems.

The claims in the Temescal range, in San Bernardino county, as well as the locality near San Diego, California, will possibly produce specimens of this mineral equal to that from Durango, Mexico.

The important occurrence at the Broad Arrow mines, 2 miles from Ashland, Clay county, Alabama, may produce both the crystals and the stream tin. The Black Hills of Dakota locality is a fine one for the gem. On Jordan creek, Owyhee county, Idaho, Prof. W. P. Blake mentions very fine specimens of wood tin one-eighth to one-half inch across, of very pure and clean material. Cassiterite has also been found in large quantities in North Carolina, though scarcely any of these localities have produced a single fine gem.

Chondrodite.—The finest known crystals of chondrodite, and the finest known gems of this mineral, have been found at the Tilly Foster mine, Brewster's, New York. The gems are few in number, and one of the finest is a cut stone (*c*) measuring one-half by one-quarter inch, of a transparent garnet color. Another(*d*), an essonite-colored crystal, is one-quarter by one-eighth inch, and another(*e*), of a red essonite color, is one-quarter by one-quarter inch. The two latter, though uncut, would furnish fine gems. The finest of these crystals are in the Allen cabinet, now at the Johns Hopkins University, and in the mineralogical cabinet of the Peabody museum. The gems are so few as only to serve for mineralogical rarities.

Turquois.—Mr. Bernard Moses recently brought to New York a series of finely colored specimens of the American varieties of turquois, obtained at Mineral Park, Mohave county, Arizona. They were from

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[a] Cabinet of Gideon Bearce, West Minot, Maine.

[b] George Rogers: "Geological Report of Pennsylvania," Vol. II., page 685.

[c] Cabinet of F. A. Canfield.

[d] Cabinet of C. Bullman.

[e] Cabinet of F. A. Canfield.

three veins, varying in width from 1 to 4 inches, about 100 yards apart, running almost parallel and traceable for nearly half a mile. They show evidences of having been worked by the Indians and Spaniards, and a large number of stone hammers were found.

One of the largest masses of the American turquois is in the possession of Prof. W. P. Blake; it is $2\frac{1}{8}$ inches long, $1\frac{3}{4}$ inches wide, and weighs 75.5 grams.

No work is carried on at present at the Los Cerillos mines, the recent investment to work that locality having proved unsuccessful. Some of the specimens sent east showed a fine blue color, which, however, was artificial, as proved by dipping for a moment in ammonia. Along the line of the railroad turquqis is sold to some extent by the Indians of the San Domingo pueblo, New Mexico, the men, women, and children coming some distance from the road to sell them. They are ground into round or heart-shaped ornaments, which are drilled with a crude form of bow-drill called by them "malakates." The drilling point is made of either quartz or agate, and the wheel to give it velocity was in one instance made of the bottom of a cup. The selling price of the ornaments is now very low. Rev. R. T. Cross states that one string made up of many hundreds of stones was valued at the price of a pony. Turquois was used by the ancient Mexicans to inlay obsidian ornaments, and also together with pyrite for making mosaic inlays and incrustations, thus forming many rich and curious effects.

Hoffmann (*a*) mentions turquois from the mountains 5 miles north of Columbus, Nevada. The specimens are of a pale blue color, although some fine ones have been obtained.

Very little of the American turquois seems to find sale except as tourists' souvenirs or mineralogical gems; yet for ornamental or inlaying work it might have quite a sale, were it properly introduced, as the green color would contrast favorably with many stones or wood.

Hematite.—See 1882 report.

Ilvaite.—Mr. R. D. Rand (*b*) observed some small black crystals of ilvaite in a narrow calcite vein in gneiss at Flat Rock tunnel on the Philadelphia and Reading railroad, opposite Manayunk.

This mineral forms a curious deep black gem and is one of the few that can be used to represent the initial "I" in jewelry work made up of the initial letters of gems. It would also represent the letter "Y," although the name yenite has been rejected.

It is reported as occurring with hornblende and magnetite, traversing quartz, in slender brown-black or black crystals at Cumberland, Rhode Island, and formerly also at Milk Row quarry, Somerville, Massachusetts. No material for really fair gems has as yet been found in the United States.

Pyrite.—The small groups of brilliant pyrite occurring with the slate

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[a] "Mineralogy of Nevada."

[b] "Preliminary report on the Mineralogy of Pennsylvania," page 22.

found through the coal regions, are trimmed and cut into ovals, squares, and other shapes, and sold for mounting as scarf pins, lace pins, ear rings, and ring stones, as well as other ornaments. Fine single crystals are also sold for ornaments, principally at Mauch Chunk and the summit of the Switchback road, and by the local jewelers at Ashland, Shenandoah, and Mahoney City. The finest specimens used here are from the Raven Run mine, 6 miles from Mahoney City.

Many fine single crystals with a very high polish have been found at Black Hawk and other localities in Colorado, which are often sold for ornaments, just as they are found, at Denver, Colorado Springs, and other places in the West. These are compact enough to cut into the faceted gem, known in Europe as "marcasite," which has been almost entirely superseded by bright steel jewelry.

Diopside.—Associated with the garnets from Fort Defiance (Arizona), Gallup (New Mexico), and other localities in that vicinity, small pieces of almost emerald-green diopside are found—evidently a chromium diopside similiar to that found with the South African diamonds. As a rule they are too small to afford gems of any value, but a few pieces have been found that are of sufficient size for very small gems. This would be a very desirable addition to the list of American gem localities, if the specimens were found in any size or quantity.

At the De Kalb (New York) locality, some very large crystals were found in 1884, several over 3 inches long and 1 inch thick, with clear spots of gem material, promising to afford cut stones weighing 20 to 30 carats.

FELDSPAR GROUP.

The greenish variety of orthoclase, called lennilite by Dr. Isaac Lea(*a*), found at Lenni Mills, Delaware county, Pennsylvania; the pearly variety called delawarite by Dr. Lea, and the bluish-green subtransparent of an aventurine character, the bright particles being hexagonal hematite (?), called cassinite by Dr. Lea, found at Blue hill, 2 miles north of Media, are all at times of fine enough color to make a common gem or ornamental stone.

Large bowlders of labradorite are often met with in the towns of Lewis, Moriah, McIntyre, Newcomb, and Westport, also in Green, Lewis, Orange, Schoharie, Saint Lawrence, and Warren counties, New York. Within a few miles of Amity, in Orange county, Mr. Silas C. Young broke up a mass of fine material for specimens, weighing over two tons, that showed the chatoyant play of colors very well.

In Pennsylvania it occurs at Mineral hill, Chester county, and opposite New Hope, Bucks county; and also in the Wichita mountains, Arkansas.

Mention is made by Genth and Kerr(*b*) of a curious white variety as occurring at the Cullakenee mine, Clay county; also, large crystals in

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a "Proceedings Philadelphia Academy of Sciences," May, 1866.

b "Minerals and Mineral Localities of North Carolina," page 48.

the trap at Shiloh Church. On the road to Charlotte, Mecklenburg county, and near Bakerville, on Toe river, specimens showing a slight blue chatoyancy are also found.

Rockport, Massachusetts, formerly afforded many finely colored pieces of amazonstone. Some fine green crystals have also been found at Paris, Maine, and at Mount Desert material that will cut into fair gems is occasionally met with.

One large, fine light green crystal, over 6 inches long, was found near Amelia Court House, at the microlite locality.

On the John Smith farm, Middletown, Delaware county, Pennsylvania, many shades of green feldspar, passing into the cassinite and delawarite, are found in the soil in loose bowlders up to 20 inches in diameter.

Elæolite.—The elæolite of Gardiner and Litchfield, Maine, would admit of a very good polish, and at times the color is greenish and would look quite well. Some of the Salem, Massachusetts, variety would also do for this purpose.

Leopardite.—A compact variety of orthoclase, which is spotted with hydrated sesquioxide of manganese, called leopardite(*a*), is abundantly found near Charlotte, Mecklenburg county, and also in Gaston county, North Carolina. It is a variety of porphyry with crystals of disseminated quartz. This material is found in large masses and would furnish a good ornamental stone if polished. It would also furnish material for a cheap gem stone.

Moonstone.—At Van Arsdale's quarry(*b*) near Feisterville, Bucks county, Pennsylvania, orthoclase is found in crystals from one-half to 2 inches in length, usually, however, in cleavage masses of gray or grayish-black colors, which show the blue chatoyancy, as well as many varieties of labrador spar, and make a very fine variety of moonstone.

The albite occurring in such beautiful specimens at Mineral hill, near Media, in Middletown, Delaware county, Pennsylvania, shows the blue chatoyancy remarkably well, and is there called "moonstone." It might well be, and is doubtlessly rightfully classed under this head, since the appearance differs so slightly from an orthoclase moonstone, and it is the effect that really gives it its name.

The greenish-gray granular albite or oligoclase found in the serpentine at the magnesia quarries, West Nottingham township, Chester county, Pennsylvania, shows a faint blue moonstone luster.

The beautiful feldspar found by Mr. W. W. Jefferis, with the sunstone at Pearce's paper mill, shows the blue chatoyancy equal to any labrador spar. It may be the latter or oligoclase (?). The finest examples of this mineral from an American locality, very closely resembling the Ceylon in quality, transparency, and color, have been lately found

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a "Minerals and Mineral Localities of North Carolina," Genth and Kerr, page 51.

b "Preliminary report on the Mineralogy of Pennsylvania," page 89.

at Amelia Court House, Virginia, by Mr. George W. Fiss, of Philadelphia, who had two very fine gems over one-fourth of an inch across.

Peristerite has been found in some abundance in the town of McComb, Saint Lawrence county, New York, associated with common orthoclase; it occurs by the ton, and many of the specimens show the beautiful light blue chatoyant effect. Mr. C. D. Nimms has also observed this mineral as far north as Bythurst, Canada, 9 miles north of Perth; also in the towns of Pierrepont, Russell, and in at least a dozen other places in this section of New York State. Some specimens make a very fine gem stone, differing somewhat from labradorite and moonstone. Mr. Charles A. Dana, of New York, has had a number of these flesh-colored pebbles of orthoclase found on Long Island sound, near his home, at Glen Cove, New York, cut *en cabochon*, making thus a very effective salmon-colored stone.

Perthite, found so plenty in Canada, at Perth, Ontario, is likely to be found in the United States as bowlders, and possibly in place. This forms a very curious and rich-colored gem stone, with its bright aventurine reflections.

A very fine oligoclase occurs at Dixon's quarry, Newcastle county, and a fine striated variety at West Chester, Delaware county, Pennsylvania.

Sunstone.—Very good sunstone (oligoclase ?), with very fine reflections, has been found near Fairville, Pennsbury township, Pennsylvania. Sunstone (oligoclase ?) occurs at Mendenhall's lime quarries, Pennsbury, Chester county; also in Ashton township, some of which is a grayish-white color with coppery reflections; and also a curious variety of sunstone in moonstone (albite) is found, showing double reflections.

A very fine green and red sunstone is found near Media. On John Scofield's farm, in Middletown township, Delaware county, moonstone and sunstone in small nodular lumps are scattered through the soil. About 1 ton has been taken out since the locality was discovered. On John Hibberd's farm, in the same township, moonstone in bowlders is found. A very fine sunstone, the orthoclase of which is a very rich salmon color and quite transparent and streaked with white, showing the aventurine effect beautifully, is found at Glen Riddle, Delaware county.

Another beautiful variety is found in the hornblende at Kennett township, Chester county; this, Dr. Genth thinks, is most probably an oligoclase. The greenish orthoclase, sometimes in bright green pieces, also pale green, and at times much spotted with brownish tints, all showing a very good sunstone effect, is found at Mineral hill, Middletown, and in Upper Providence, Delaware county. The orthoclase of Frankford, Pennsylvania, with the göthite disseminated through it, approaches the sunstone in appearance very closely.

On the Horace Greeley farm, at Chappaqua(*a*), New York, small pieces

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a "Proceedings New York Academy of Sciences," Vol. I.

of an orthoclase sunstone were found, almost as fine as any of the Norwegian.

Obsidian.—Smoky, transparent obsidian that would cut well, and form a curious variety somewhat resembling the "Moravian bottle glass" (moldavite), but not so green, has been found in rounded pebbles, over 1 inch across, near Santa Fé, Mew Mexico.

A porphyritic and spherolitic obsidian is found under the trachyte on Gunnison river, and a heavy vein of porphyritic obsidian near the Rio Grande pyramid, continuing from there southward through the trachytic bed. Nodules occur in the lower members of the trachytic veins.

A dike of obsidian, light gray and clear with concentric structure, sets from the Colorado Central lode near Georgetown, north of Saguache creek. Hoffmánn mentions obsidian in fine pieces and very abundant as occurring 10 miles southeast of Silver Peak, Nevada. Across the State line, 5 miles in Owen valley, California, it is found in red fragments, and also banded with alternate layers of black and brown. Obsidian occurs in large, fine black pieces, and mottled black and brown, and in small layers, in a moss rock at Obsidian cliffs, Yellowstone park.

Octahedrite.—Octahedrite is reported as occurring in small crystals at Dexter's lime rock at Smithfield, Rhode Island, and in flat tabular glassy crystals of a pale green color and very brilliant in the gold sands of the Brindletown mine([a]), Burke county, North Carolina. These would possibly afford small gems, nothing, however, to compare with the beautiful blue crystals from Brazil, so splendent at times as to be mistaken for diamonds.

Brookite, arkansite, microlite.—At the Ellenville, Ulster county, New York, lead mines some remarkable flat, ruby-red crystals of brookite have been found, and at Magnet cove, Arkansas, remarkably brilliant crystals of the variety of this mineral known as arkansite occur in great profusion, at times a transparent honey yellow. The mineral does not, however, readily admit of polish. One fine crystal of microlite in the cabinet of Mr. C. S. Bement, is about three-eighths of an inch long, and in part a rich honey-yellow color, having all the color of topazolite, with a higher luster. This might possibly be added to the list of American gem minerals. This crystal was found at Amelia Court House, Virginia. Some few of the microlites found at the Amelia Court House locality are of sufficient transparency to afford gems, the color ranging from an essonite red to that of a rich spinel yellow and remarkably brilliant.

Microlite has the highest specific gravity of any known gem, being about 6.

Ilmenite.—At Magnet cove, Arkansas, the ilmenite is found in such fine bright crystals as to form natural ornaments, and will, besides, admit of a fine brilliant polish.

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[a] "Minerals and Mineral Localities of North Carolina," 1881 page 84.

Allanite.—The allanite found in large masses and crystals in Amherst county, Virginia, is very compact and bright black in color, and would form a black metallic gem stone.

Sodalite, cancrinite.—At Litchfield and South Litchfield, Maine, sodalite, elæolite, and cancrinite are found in bowlders in size from that of the fist to those weighing many tons. They lie scattered over the surface for a distance of about 4 miles. One mile and a half west of this line, across a pond in West Gardiner, these minerals are found associated with zircon, as in South Litchfield. On some of the West Gardiner farms there are ledges of rocks that are evidently the source of these bowlders. The bowlders occur principally on the farms of Moses True, Capt. Joseph Wharff, and Rufus Smith.

The deep-blue and azure-blue sodalite and cancrinite, a rich yellow, and occasionally in hexagonal crystals, occur sparingly in seams in this tough elæolite and lepidomelane rock. The seams are from 1 millimeter to very nearly 1 inch in thickness; some of the white seams found are evidently altered sodalite; the cancrinite has been found 2 inches thick.

Violet and azure-blue sodalite have been found associated with elæolite, biotite, and zircon in a syenite vein at Salem, Massachusetts. Enough has been found within the last two years at South Litchfield to give it some gem importance. A number of distinct hexagonal crystals of fine waxy yellow cancrinite, as a rule embedded in the deep-blue sodalite, have also been found; also pink and greenish masses, and masses of rich yellow, 2 inches in thickness, which could be used the same as sodalite.

Scapolite.—The pink and purplish scapolite found at Boston, Massachusetts, will polish nicely and form a neat ornamental gem stone.

Lazulite.—Lazulite in dark-blue crystals and crystalline masses is found at Crowder's and Chubb's mountains in Gaston county, North Carolina, and at Coffee Gap, Sauratown mountains, Stokes county. At Graves mountain, Lincoln county, are found the finest sky and dark-blue crystals known. This mineral would make an opaque gem or ornamental stone, as the color, although lighter, is often as rich as lapis-lazuli.

Cobaltite is occasionally cut abroad and resembles a flesh-colored pyrite when cut. It is not found of fair quality at any American locality.

Zincite, franklinite, and willemite[a], as found intermixed in the zinc mines at Franklin, New Jersey, are at times ground into charms and paperweights and ornaments of different kinds, principally by the miners. They do not admit of a very fine polish, however, though they present a good appearance. A curious brown serpentine containing zinc, described by Prof. C. U. Shepard, was also cut and polished by the miners here.

Enstatite and bronzite.—Enstatite and bronzite are found half a mile

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[a] See also "Mineral Resources of the United States, 1882," page 496.

west of Texas, Pennsylvania, and in beautiful massive foliated varieties. Bronzite was observed by Dr. Genth (*a*) near Crump's serpentine quarry, near Media, in Middletown township, and also near Henry Hipple's, in Marple township, forming the mass of Castle rock; also in Newton township near the lime kiln, and near Radnor's, Delaware county. Bronzite and enstatite occur in large quantities at Bare Hills, Maryland.

Titanite.—At Bridgewater station, Delaware county, Pennsylvania, some remarkably fine crystals of titanite have been found. Some of them, over 1 inch long and very transparent in parts, are a rich greenish yellow and a vitreous golden, equaling in color the finest from the Tyrol, and some would afford gems weighing from 10 to 20 carats each, that would show a play of colors rather adamantine than opalescent. Some of the fine crystals from this locality are now in the cabinet of Mr. C. S. Bement, the W. S. Vaux cabinet, Academy of Natural Sciences, Philadelphia, and in the Peabody museum, New Haven.

Many yellow crystals (*b*) over 1 inch long have been found in the hornblendic gneiss on the Schuylkill near Philadelphia, and yellow crystals with sunstone at W. Cloud's farm and Pearce's paper mill, in Kennett township, Chester county, Pennsylvania.

Chlorastrolite.—One of the largest known perfect chlorastrolites is in the cabinet of Mr. M. T. Lynde, of Brooklyn, Long Island, a gem measuring 1½ by 1⅛ inches. A fine pair of chlorastrolites over half an inch across are in the possession of Mr. F. A. Canfield.

Datolite.—The compact, opaque, white, creamy, and flesh-colored varieties of datolite found at the Minnesota, Quincy, Marquette, Ashbed, and other mines in the copper region of Lake Superior, admit of a very high polish, and make an excellent opaque gem or ornamental stone. Notably one especially fine nodule over 4 inches across, with a flesh-colored center shading off into gray and creamy tints, was found at the Delaware mine, and is in the cabinet of Mr. C. S. Bement.

Thompsonite.—Large quantities of thompsonite have been cut into gem stones during the last year, the cutting consisting almost entirely of a rounding off of the pebble so as to show the concentric and other markings to the best perfection. Some of them, over an inch in diameter, have been polished. As a rule the small ones are the finest material. The lintonite is really a variety of the thompsonite and polishes very nicely, either alone or when occurring with the flesh-colored forms of thompsonite.

Natrolite.—Many veins of natrolite, and more particularly one large surface, representing over 300 square feet of the mineral, were met with at shaft No. 2 of the West Shore railroad, at Weehawken, New Jersey. Although this quantity afforded millions of crystals, scarcely any were stout enough to afford gems of this beautiful limpid and white mineral,

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[a] "Preliminary report on the Mineralogy of Pennsylvania," page 63.

[b] *Ibid.*, page 27.

so abundantly found here and all along Bergen hill where any tunneling has been carried on.

Fine crystals are found in the Lake Superior copper region. None has been sold for gems in the United States, though it is occasionally used as an initial gem for the letter "N" in initial jewelry.

Pectolite.—Among the Eskimo implements collected by the United States Signal Service at Point Barrow, Alaska, and examined by Prof. F. W. Clarke(*a*), was a supposed jade, which he found on analysis to be a new and interesting variety of compact light-green pectolite; specific gravity, 2.873. This was obtained from some point east of Point Barrow, on the Kowak river, and forms an interesting and unexpected addition to this line of gem stones.

Apophyllite (also called fish-eye stone) is really too soft for gem purposes, though repeated references are made to it by gem writers.

The Erie tunnel, Bergen hill, afforded thousands of fine doubly-terminated detached crystals, less than one-fourth inch in diameter, that were really beautiful as ornaments; this same tunnel afforded a single crystal 4 inches in diameter. Some beautiful ones have also been found at the Cliff mine and other localities in the Lake Superior copper region, at times being perfect specimens of limpidity. The West Shore railroad tunnel at Weehawken, New Jersey, was the first locality in the United States to produce pink and flesh-colored crystals. Many beautiful ones were found here, though not as fine as the Andreasberg or the Mexican varieties. This and the Lake Superior locality would both afford material for cutting.

Apatite.—Apatite was found in such remarkably perfect and fine-colored crystals at the tourmaline locality at Auburn, Maine, by Mr. N. H. Perry, that the hill on which the tourmalines were found has been named Mount Apatite. These crystals were transparent green, pink, and violet, and so much resembled tourmaline as at times to have been mistaken for it. Some of the local collectors attempted cutting some of them, but the hardness is too low for a transparent gem.

Crocidolite.—Crocidolite was observed by Col. Joseph Wilcox(*b*) in long, delicate fibers of a blue color, in one of the western counties of North Carolina.

Mr. Theo. D. Rand found a dark-bluish, fibrous mineral at the Falls of the Schuylkill, and Prof. W. T. Roepper (*c*) found at Coopersburg, associated with white and brownish-white garnet, bluish-white crystalline fibrous coatings, which may belong here.

Crocidolite was also observed near Cumberland, Rhode Island, and at Eland Fountain, Orange river, New Jersey, though none of gem value has yet been found in the United States.

Serpentine.—The many fine varieties of serpentine found in the United

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a American Journal of Science, III., Vol. XXXVIII., page 63.

b "Minerals and Mineral Localities of North Carolina," 1881, page 41.

c "Preliminary report on the Mineralogy of Pennsylvania," page 10.

States would admit of use in some cases as ornaments. The dark-green noble serpentine of Newburyport, Massachusetts, was cut into oak and other leaf-like forms, very effectively indeed, by Mr. F. Osgood, of that place. The handsome yellow serpentine of Montville is also of the precious variety.

The beautiful varieties of serpentine or verd antique from Harford county, Maryland, admit of a fine polish.

The serpentines of Saint Lawrence county, as also those of Cornwall, Monroe, and Warwick townships, Orange county, the ophiolite of New York city and vicinity, the serpentine of New Rochelle, New York, also some of the Hoboken, New Jersey, and the Staten Island varieties are useful for ornamental and occasionally for gem purposes.

At Stoneham, Maine, green and red damourite(*a*), altered from topaz, was cut into different odd forms and charms by local collectors. At Deer Isle, also, serpentine of a very light-green color occurs.

The serpentine of Texas, Mineral Hill, Newtown, Marple, Middletown, and other localities in Delaware county, Pennsylvania, are also very fine.

The serpentine from the neighborhood of Patterson(*b*), Caldwell county, North Carolina, is of a dark greenish-black color, and admits of a fine polish.

The serpentinous substance named pelhamine by Prof. C. U. Shepard(*c*) admits of a very good polish and with a very curious effect.

Dr. F. A. Genth mentions as being found at Easton, Pennsylvania, a bowenite frequently containing a small quantity of tremolite; it is of a greenish and reddish-white color and of great tenacity. This is evidently the so-called jade mentioned in the report for 1882. The easy working of this material, and the effective designs that can be made from it, recommend it as having fully as much merit for tourists' jewelry as the various teeth, beans, and other like things that are sold for this purpose.

Fluorite.—The clear varieties of colored transparent fluorite are designated as false ruby, emerald, sapphire, topaz, amethyst, etc. Many fine specimens of the green have been found at Muscalonge lake, Saint Lawrence county, New York, at times crystals over 1 foot across.

The Hardin county, Illinois, localities are the largest deposits in the United States, and some thousands of tons are annually mined here; crystals of the richest purple, yellow, red, rose-colored, green, and other varieties are very common. It differs from the English in that the crystalline faces in nearly all cases are dull and the colors show only by transmitted light. Some crystals 1 foot across were observed here.

On the Cumberland river, Tennessee, some of the finest American crystals of a blue-green variety have been found; wine and honey-

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a *American Journal of Science*, May, 1885.

b Genth and Kerr's "Minerals of North Carolina," page 57.

c "Contributions to Mineralogy," 1876.

yellow ones also at Saint Louis, Missouri, in the geodes in the limestone. Fine crystals are found at Pike's peak, Colorado.

One of the most remarkable varieties of this mineral is a chlorophane from the microlite localities[a] at Amelia Court House, Virginia. This fluoresces by the heat of the hand, and when a cut stone was placed in a vial of warm water, showed distinctly in a dark room, thus making a new form of gem, *i. e.*, a fluorescent gem stone, though not hard enough for any kind of wear.

Fossil coral.—The Iowa fossil corals have during the last year been sold more largely than heretofore for jewelry, paper weights, and specimens. One Philadelphia lapidary states that he sold over $250 worth in one year. It is sold to some extent at Iowa City and other places in Iowa, as well as at the regular tourists' stopping places all over the United States.

Lepidolite.—Lepidolite has been found in large quantities in the past at Mount Mica, Paris, Maine, which has afforded masses of 50 pounds of very fine color; at Hebron and Norway, and more recently at Auburn, also at Mount Black, Rumford, Maine. As this mineral is used to some extent abroad for ornaments, such as dishes, vases, paper weights, etc., the similar utilization of the American material is suggested.

Aragonite and satin spar.—The aragonite "satin spar," from near Dubuque, Iowa, especially in such fine form as at Rice's cave, and in such remarkably fine forms as the "floss ferri" variety, from near Rapid City, Dakota, would admit of the same uses as common satin spar.

The satin spar (gypsum) ornaments, such as beads, eggs, and a variety of others, sold at Niagara Falls and many of the tourist places, are almost without exception imported from Wales, though some few common white gypsum ornaments are at times cut from gypsum found near Niagara. On Goat island large masses are often found, and occasionally even under the falls, where all the material for all the ornaments sold here is supposed to have been found. Fine selenite occurs here, but no satin spar.

Malachite.—One very fine, compact, fibrous mass of dark green malachite, that would cut a beautiful cube 1 inch square, from the McCulloch mine, Virginia, is in the cabinet of Mr. C. S. Bement.

Hoffmann mentions it in massive concretions in Copper cañon, Galena district, and at Mineral Hill, Nevada. Some of the copper mines of Arizona and New Mexico will undoubtedly furnish fine specimens when they are more developed.

Mr. F. E. Monteverde has some gem specimens of malachite of very good quality, over 1 inch across, from the Copper Queen mine, Bisbee, Arizona. Malachite has been found recently at the Globe and Arizona mines in fibrous and mammillary masses, and in seams from 3 to 4 inches in thickness and of very fine color, in many respects equaling the finest

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[a] *American Journal of Science*, July, 1884.

from Russia. A number of fancy articles have been made from it. At Ducktown, Tennessee, some fine radiated masses have been found that would polish well.

At the Jones mine, Berks county, Pennsylvania, very dark green and finely mottled malachite was found that would cut into fine gems over 2 inches across. Some very fine specimens from here are in the cabinet of Mr. W. W. Jefferis. The material from this locality equals any from Russia, but the supply is very limited.

Malachite is found in North Carolina in Guilford, Cabarrus, and Mecklenburg counties. At Silver Hill and Conrad Hill, in Davidson county, the fibrous variety has been observed, and at a number of other localities in the State, but rarely of any gem value. In the United States subtreasury, in New York City, are a few fine gem pieces of malachite from the Copper Knob mine in Ashe county, North Carolina.

Chrysocolla.—A beautiful compact chrysocolla, mixed with quartz, is found at the Allouez mine, Houghton, Lake Superior region. Some of the specimens would furnish fine, rich, bluish-green gems one-half inch square.

Beautiful specimens, botryoidal and massive, greenish blue in color, have been found at the Jones mine, near Morgantown, Berks county, Pennsylvania; and a fine specimen from some Arizona locality, coated with chalcedony, made some beautiful gems when the chalcedony was polished, allowing the botryoidal chrysocolla to show through. In one case these markings resemble a human head.

Anthracite is used to some extent as jewelry, being carved and turned into small trinkets, such as compass cases, boots, hearts, anchors, and other small charms. It could readily be made into beads and round ornaments to be used for scarf pins, lace pins, bracelets, etc., in the same way as jet. It is also turned into cups, saucers, vases, candlesticks, and paper weights, and is carved by hand into a variety of small ornaments. The objects made often have one or more ridges of the rough coal, the other portions being highly polished, thus making a striking contrast. Most of the anthracite is worked at Mountain Top, near Glen Summit, Lucerne county, Pennsylvania. The material used is obtained at the Franklin mine at Ashley, the Spring Tunnel mine at Summit Hill, and at Nanticoke, Pennsylvania. These articles are sold at Scranton, Wilkes Barre, Pittston, Mauch Chunk, and at the Summit Hill station on the Switchback railroad. From $2,500 to $3,000 worth of these anthracite objects are sold annually.

Catlinite or pipestone.—Catlinite, which is found in such large quantities in the Upper Missouri region, and especially in Pipestone county, Minnesota, is worked into a large variety of ornamental pipes, that are sold at from 75 cents or $1 each to as much as $5 and $10; at times as high even as $20 for very large pieces of carving. They are made in a variety of forms, mainly to sell readily, such as tomahawks with the pipe bowl in the back, and often pipes from 10 to 24 inches long have one or more figures on the stem, which is sometimes made of several pieces, usually, however, of wood. Parts of the pipes are often laid out in designs that are filled in with lead.

This stone is also worked into a variety of ornaments and into small charms of different kinds. These are offered and find a ready sale to persons visiting Minnehaha Falls, Lake Minnetonka, various hotels in Saint Paul and Minneapolis, and other cities in Minnesota and Dakota as far west as Fort Sully. The amount sold annually is perhaps $10,000 to $15,000 worth. This stone should surely find more uses from its compactness, easy working, and the fine polish it admits of. One curious spotted variety is very beautiful, and would make a good contrast with the regular red pipestone.

Catlinite is also found at Rice lake, Barron county, Wisconsin.

Amber.—Before the New York Academy of Sciences, February 5, 1883, I exhibited and described an elongated, twisted mass of amber(*a*) of a rich yellow color, but opaque, weighing 12 ounces, that had been found on the shore at Nantucket, Massachusetts, evidently from the Tertiary deposits there. This mass more closely resembled the true amber than any other American specimen yet seen.

The Rev. Phœbe Hanaford, at the same meeting, mentioned having found a small piece weighing about 1 ounce at the same locality. Amber has also been found at Martha's Vineyard and at Gay Head.

In a paper read before the New York Academy of Sciences, on the same date, I described a mass of amber 20 inches long, 6 inches wide, and 1 inch thick, and weighing 64 ounces, found at Kirby's marl pit, on Old Man's creek, near Harrisonville, Gloucester county, New Jersey. A one-fourth-inch section showed a light grayish-yellow color. A section one-fourth inch thick showed a light, very transparent yellowish-brown color. The entire mass was filled with botryoidal-shaped cavities filled with glauconite or greensand and a trace of vivianite. The hardness is the same as the Baltic amber, only slightly tougher and cutting more like horn, and the cut surface showing a curious pearly luster, differing in this respect from any other amber yet examined by me. This luster is not produced by the impurities, for the clearest parts show it the best. It admitted of a good polish. The specific gravity of a very pure piece of the carefully selected amber is 1.061, which is the lowest density on record, the usual amber range being from 1.065 to 1.081. It ignites in the same way as other ambers. It was found at a depth of 28 feet and under 20 feet of the Cretaceous marl, the amber being found in a 6-foot stratum of fossils.

Dr. N. L. Britton has observed traces of amber near Camden, New Jersey, in the Cretaceous deposits.

Dr. Charles C. Abbott(*b*) mentions having several times found small grains or pebbles of amber in the bed of Crosswick's creek. These he

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a Now in the Amherst College cabinet.

b *Science,* Vol. I., page 594.

gave to Mr. W. S. Vaux, of Philadelphia, and they are now at the Academy of Natural Sciences. He suggests that they are derived from the beds of clay which are exposed in the bluff forming the southern bank of the creek. There are Cretaceous clays nearer Trenton than Crosswick's creek, in which occurs much fossil wood; in and on this grains of amber are not uncommon; they are usually very small and difficult to detect. The wood is soft and very recent in appearance, burning with an uncertain, flickering flame. The amber is evidently derived from the sap of the wood.

The late Professor Kerr(*a*) mentioned the finding of succinite in lumps of several ounces weight in Pitt county and elsewhere, in the Tertiary marl beds of the eastern counties of North Carolina.

Dr. Troost(*b*) mentions that at Cape Sable, on the northern side of Magothy river and western shore of Maryland amber of several varieties occurs. One is entirely opaque in concentric zones of every shade of red, yellow, and brown, thus displaying the most beautiful colors; another is a transparent yellow, and another is an earthy porous variety. It is found here in the lignite beds in some quantity. It also occurs on the Chesapeake and Delaware canal in Kent county, Delaware.

Mr. C. G. Yale, of San Francisco, California, says that amber is common in the lignite deposits on the peninsula of Alaska. It is also obtained in the alluvium in the delta of the Yukon river and in the vicinity of most of the Tertiary coal deposits on the Fox islands, being everywhere an article of ornament with the natives, who carve it into rude beads.

At no American locality is amber found of commercial value, and although the specimens above referred to are all called amber, they are undoubtedly, with the exception of the Nantasket amber, all from different trees from those producing the Baltic amber, and analyses of them would prove of considerable interest.

Jet.—Jet occurs in the Wet Mountain valley, Trinchera mesa, southeast Colorado, and in the coal seams of most coal-bearing rocks of Colorado. The beautiful specimens of El Paso county, although sold largely for specimens, are very little if at all used for ornamental purposes, from the fact mainly that although this perhaps rivals any known jet, black onyx has almost entirely superseded this material in the United States, owing to the greater hardness of the onyx and the cheapness with which it is furnished from Oberstein and Idar.

Meerschaum.—Sepiolite, or meerschaum, has occasionally been met with in compact masses of smooth earthy texture in the magnesia quarries in West Nottingham township, Chester county, Pennsylvania. Only a few small pieces have been found, but they were of good quality. It also occurs in grayish and yellowish-white masses in the serpentine near Stamp's tavern, in Concord township, Delaware county.

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[a] "Minerals and Mineral Localities of North Carolina," page 83.

[b] *Silliman's Journal*, page 182, 1832.

Masses weighing 1 pound, of a pure white material, have been found on the John Smith farm, Middletown, in the same county.

It has been observed at the Cheever iron mine, Richmond, Massachusetts, of equally good quality, in pieces over 1 inch across.

It has also been found in the serpentine at New Rochelle, Westchester county, New York.

PRODUCTION OF PRECIOUS STONES IN THE UNITED STATES.

While it is impossible to obtain exact returns of the values of the precious stones found in the United States, it is believed that the estimates given in the following table represent, roughly, the total values and the proportionate values of the several mineralogical species. Gold quartz, the value of which should be more properly perhaps included under the head of gold mining, is added at the close of the list.

Estimated production of precious stones in the United States in 1883 *and* 1884.

Species.	1883.			1884.		
	Value of stones found and sold as specimens and curiosities, occasionally polished to beautify or show structure.	Value of stones found and sold to be cut into gems.	Total.	Value of stones found and sold as specimens and curiosities, occasionally polished to beautify or show structure.	Value of stones found and sold to be cut into gems.	Total.
Diamond	....	....	....	....	$800	$800
Sapphire gems	$200	$2, 000	$2, 200	$250	1, 500	1, 750
Chrysoberyl	100	....	100	25	....	25
Topaz	1, 000	....	1, 000	200	300	500
Beryl	200	300	500	300	400	700
Emeralds	500	....	500	....	....	....
Hiddenite	100	500	600	....	....	....
Tourmaline	....	....	....	1, 500	500	2, 000
Smoky quartz	2, 500	7, 500	10, 000	2, 000	10, 000	12, 000
Quartz	10, 000	1, 500	11, 500	10, 000	1, 500	11, 500
Silicified wood	5, 000	....	5, 000	10, 000	500	10, 500
Garnets	1, 000	5, 000	6, 000	1, 000	3, 000	4, 000
Anthracite	....	2, 500	2, 500	....	2, 500	2, 500
Pyrite	1, 500	500	2, 000	2, 000	1, 000	3, 000
Amazonstone	3, 500	250	3, 750	2, 500	250	2, 750
Catlinite	10, 000	....	10, 000	10, 000	....	10, 000
Arrow points	1, 000	....	1, 000	1, 000	....	1, 000
Trilobites	500	....	500	500	....	500
Sagenitic rutile	500	500	1, 000	500	500	1, 000
Hornblende in quartz	500	100	600	500	100	600
Peridot	50	250	300	50	100	150
Thompsonite	250	500	750	250	500	750
Diopside	200	100	300	....	....	....
Agate	1, 000	500	1, 500	4, 000	500	4, 500
Chlorastrolite	500	1, 000	1, 500	500	1, 000	1, 500
Turquois	1, 500	500	2, 000	1, 500	500	2, 000
Moss agate	1, 000	20, 000	21, 000	1, 000	2, 000	3, 000
Amethyst	2, 000	250	2, 250	2, 000	250	2, 250
Jasper	2, 000	500	2, 500	2, 000	500	2, 500
Sunstone	250	200	450	250	200	450
Fossil coral	500	250	750	500	250	750
Total	47, 350	44, 700	92, 050	54, 325	28, 650	82, 975
Gold quartz	40, 000	75, 000	115, 000	40, 000	100, 000	140, 000

IMPORTS.

Diamonds and other precious stones imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Glazier's.	Dust.	Rough or uncut.	Diamonds and other stones not set.	Set in gold or other metal.	Total.
1867	$906	......	......	$1, 317, 420	$291	$1, 318, 617
1868	484	......	......	1, 060, 544	1, 465	1, 062, 493
1869	445	140	......	1, 997, 282	23	1, 997, 890
1870	9, 372	71	......	1, 768, 324	1, 504	1, 779, 271
1871	976	17	......	2, 349, 482	256	2, 350, 731
1872	2, 386	89, 707	......	2, 939, 155	2, 400	3, 033, 648
1873	......	40, 424	$176, 426	2, 917, 216	326	3, 134. 392
1874	......	68, 621	144, 629	2, 158, 172	114	2, 371, 536
1875	......	32, 518	211, 920	3, 234. 319	......	3, 478, 757
1876	......	20, 678	186, 404	2, 409, 516	45	2, 616, 643
1877	......	45, 264	78, 033	2, 110, 215	1, 734	2, 235, 246
1878	......	36, 409	63, 270	2, 970, 469	1, 025	3, 071, 173
1879	......	18, 889	104, 158	3, 841, 335	538	3, 964, 920
1880	......	49, 360	129, 207	6, 690, 912	765	6, 870, 244
1881	......	51, 409	233, 596	8, 320, 315	1, 307	8, 606, 627
1882	......	92, 853	449, 313	8, 377, 200	3, 205	8, 922, 771
1883	......	82, 628	443, 996	7, 598, 176	2, 081	8, 126, 881
1884	22, 208	37, 121	367, 816	8, 712, 315	(*a*)	9, 139, 460

a Not specified.

Imports of substances not included in the foregoing table, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Unmanufactured agates.	Bookbinders' and other manufactured agates.	Carnelian.	Brazil pebbles.	Amber.	Amber beads.	Unmanufactured coral.	Manufactured coral.	Unmanufactured meerschaum.	Total.
1868	......	......	......	......	......	......	......	$62, 270	......	$62, 270
1869	......	$70	$269	......	$427	......	......	22, 417	$6, 407	29, 590
1570	......	......	766	......	1, 433	......	......	18, 975	3, 998	25, 172
1871	......	1	661	......	180	......	......	37, 877	698	39, 417
1872	......	529	207	......	2, 426	......	$83	59, 598	2, 194	65, 037
1873	$151	1, 310	......	$1, 237	1, 534	$595	230	63, 805	5, 608	74, 470
1874	177	1, 524	......	......	1, 448	1, 057	527	28, 152	270	33, 155
1875	520	5, 165	......	57	7, 169	715	1, 278	33, 567	2, 902	51, 373
1876	293	1, 567	......	......	15, 502	187	109	33, 559	21, 939	73, 156
1877	579	1, 904	*b* 69	......	17, 307	329	718	28, 650	9, 304	58, 860
1878	82	404	......	76	13, 215	1, 119	1, 252	12, 667	16, 308	45, 123
1879	138	364	......	......	17, 821	203	147	11, 327	19, 088	49, 088
1880	57	2, 346	......	......	36, 860	2, 317	62	5, 492	30, 849	77, 983
1881	486	1, 700	......	5	42, 400	1, 102	89	2, 501	72, 754	121, 037
1882	901	5, 084	......	111	72, 479	4, 174	1, 474	669	56, 118	141, 010
1883	14	2, 895	......	......	40, 166	3, 472	681	1, 303	58, 885	107, 416
1884	......	6, 100	......	3, 496	56, 301	4, 692	158	(*c*)	43, 169	113, 916

b Not separately classified since 1877.

c Not specified.

FERTILIZERS.

PHOSPHATE ROCK.

By David T. Day.

All the natural sources which yield phosphorus even in very small quantity have industrial value in furnishing this element for fertilizers. First among these sources are the different varieties of calcium phosphate found quite widely distributed over the United States. This substance occurs as "phosphate rock" in a bed of enormous value, with its center at Charleston, South Carolina. The bed can be mined for a distance of 70 miles parallel to the coast, and has a maximum width of 30 miles, and crops out again irregularly in North Carolina; lately similar deposits have been investigated in Florida, and the phosphates of Alabama will probably assume industrial importance in the future. While these deposits have a few distinguishing features, to be spoken of farther on, they are all much more closely allied to each other than to apatite, a phosphate of calcium containing varying amounts of calcium chloride and calcium fluoride, which is the second and less important form in which phosphorus is obtained for fertilizers, and which is found irregularly distributed through the New England States towards Canada.

SOUTH CAROLINA.

There is little to be added to the description of the phosphate deposits of South Carolina, given by Mr. O. A. Moses in "Mineral Resources of the United States, 1882." The region has been explored quite thoroughly, and new beds are only continuations of old ones that have become unprofitable. About two years ago Italian laborers were introduced into the phosphate mines, but they have given place again to the negroes, who have proved more tractable and better suited to the climate. Much attention is now being paid to improvements in the dredges for river mining, the object being to secure a satisfactory method of crushing the rock at the bottom of the river. Just now (June, 1885) the phosphate industry is awaiting the results of the trial of the new Brotherhood dredge, an adaptation of the Clyde form, of which much has been said pro and con. The "clam-scoop" dredge has done well in

Beaufort river, where improvements in dredging and drying machinery are being made more rapidly than at Charleston. The Edisto and Ashepoo district is also receiving more attention than during former years.

The production of crude phosphate rock in 1883 and 1884 was somewhat greater than during any former period. This was due to more systematic methods in mining rather than to an increased demand; the prices, therefore, have been somewhat lower, $5.50 per ton being the average price for clean-washed phosphates. The West is becoming a better market for crude phosphates; 12,000 tons were shipped westward in the year 1883–'84 against 6,000 tons in 1882–'83. From June 1, 1883, to May 31, 1884, the entire yield of crude phosphates from South Carolina was 431,779 long tons; of this about three-fifths, or 252,825 tons, were shipped from the port of Charleston, and nearly all of the remainder from Beaufort; 6,329 tons were shipped from other ports. From June 1, 1884, to May 31, 1885, the production was slightly less, namely, 395,403 long tons; the proportion between the shipments from Beaufort and Charleston remained practically the same as in the previous year. A summary of the entire production in South Carolina is given in the following table:

Phosphate rock (washed product) mined by the land and river mining companies of South Carolina.

Years ending May 31—	Land companies.	River companies.	Total.
	Long tons.	*Long tons.*	*Long tons.*
1867	6	....	6
1868	12, 262	....	12, 262
1869	31, 958	....	31, 958
1870	63, 252	1, 989	65, 241
1871	56, 533	17, 655	74, 188
1872	36, 258	22, 502	58, 760
1873	33, 426	45, 777	79, 203
1874	51, 624	57, 716	109, 340
1875	54, 821	67, 969	122, 790
1876	50, 566	81, 912	132, 478
1877	36, 431	126, 569	163, 000
1878	112, 622	97, 700	210, 322
1879	100, 779	98, 586	199, 365
1880	125, 601	65, 162	190, 763
1881	142, 193	124, 541	266, 734
1882	191, 305	140, 772	332, 077
1883	(*a*)	(*a*)	378, 380
1884	(*b*)	(*b*)	431, 779
1885	(*c*)	(*c*)	395, 403

a Not reported separately.
b Not reported separately; proportion about 255,000 land, 175,000 river.
c Not reported separately; proportion about 230,000 land, 162,000 river.

A large proportion of the Beaufort rock is exported, while most of that from Charleston is used in supplying domestic manufacturers. The amount consumed by manufacturers in Charleston and Beaufort is increasing, as shown by the following table:

Detailed statement of total foreign and coastwise shipments and local consumption since June 1, 1874.

Periods.	Beaufort.	Charleston.	Other points.	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
From June 1, 1874, to May 31, 1875:				
Foreign ports	44, 617	25, 929	....	70, 546
Domestic ports	7, 000	25, 560	....	32, 560
Consumed	....	19, 684	....	19, 684
Total	51, 617	71, 173	....	122, 790
From June 1, 1875, to May 31, 1876:				
Foreign ports	50, 384	25, 431	....	75, 815
Domestic ports	9, 400	28, 831	....	38, 231
Consumed	....	18, 850	....	18, 850
Total	59, 784	73, 112	....	132, 896
From June 1, 1876, to May 31, 1877:				
Foreign ports	73, 923	28, 844	....	102, 767
Domestic ports	6, 285	40, 768	....	47, 053
Consumed	....	13, 400	....	13, 400
Total	80, 208	83, 012	....	163, 220
From June 1, 1877, to May 31, 1878:				
Foreign ports	100, 619	21, 123	....	121, 742
Domestic ports	8, 217	60, 729	....	68, 946
Consumed	....	17, 635	....	17, 635
Total	108, 836	99, 487	....	208, 323
From June 1, 1878, to May 31, 1879:				
Foreign ports	97, 799	21, 767	....	119, 566
Domestic ports	8, 618	52, 281	....	60, 899
Consumed	....	18, 900	....	18, 900
Total	106, 417	92, 948	....	199, 365
From June 1, 1879, to May 31, 1880:				
Foreign ports	47, 157	14, 218	....	61, 375
Domestic ports	13, 346	94, 002	....	107, 348
Consumed	....	22, 040	....	22, 040
Total	60, 503	130, 260	....	190, 763
From June 1, 1880, to May 31, 1881:				
Foreign ports	62, 200	8, 568	....	70, 768
Domestic ports	65, 895	91, 929	....	157, 824
Consumed	....	38, 142	....	38, 142
Total	128, 095	138, 639	....	266, 734
From June 1, 1881, to May 31, 1882:				
Foreign ports	89, 581	22, 905	....	112, 486
Domestic ports	57, 465	111, 314	7, 875	176, 654
Consumed	....	42, 937	....	42, 937
Total	147, 046	177, 156	7, 875	332, 077
From June 1, 1882, to May 31, 1883:				
Foreign ports	94, 789	28, 251	....	123, 040
Domestic ports	36, 175	150, 545	26, 000	212, 720
Consumed	....	42, 620	....	42, 620
Total	130, 964	221, 416	26, 000	378, 380
From June 1, 1883, to May 31, 1884:				
Foreign ports	132, 114	20, 539	....	152, 653
Domestic ports	34, 711	181, 363	6, 329	222, 403
Consumed	5, 800	50, 923	....	56, 723
Total	172, 625	252, 825	6, 329	431, 779
From June 1, 1884, to May 31, 1885:				
Foreign ports	111, 075	11, 495	....	122, 570
Domestic ports	30, 963	161, 700	13, 170	205, 833
Consumed	12, 000	55, 000	....	67, 000
Total	154, 038	228, 195	13, 170	395, 403

A noteworthy feature in the year 1884 was the formation in March of the Phosphate Miners' Exchange, in which the producers have joined, in order to support the interests of the trade. The organization is quite perfect, but the price of phosphate rock has not risen since its formation. The following companies and individuals are engaged in mining phosphate rock in South Carolina:

List of phosphate mining companies in South Carolina.

LAND COMPANIES.

Charleston Mining and Manufacturing Company, Ashley river.
Bolton Mines, Ashley river.
C. C. Pinckney, Ashley river.
Rose Mining Company, Ashley river.
Wm. Gregg, Ashley river.
Saint Andrews Mining Company, Stono river.
D. Roberts, Stono river.
A. B. Rose, Ashley river.
Wando Company, Ashley river.
G. A. Trenholm & Son, Ashley river.
J. F. Fishburne, Ashley river.
F. C. Fishburne, Edisto river.
L. N. Chisolm, Edisto river.
Cahill & Wise, Ashley river.
Charles H. Drayton & Co., Ashley river.
Pacific Guano Company, Bull river.
E. Willis, Charleston.
G. H. Linstedt, Charleston.
Charleston Phosphate Company, Charleston.
Dotterer & Ravenel, Charleston.
D. W. Ebaugh, Charleston.
W. L. Bradley, Rantowle's creek.
C. O. Campbell, Charleston.
Wm. Wilkinson, Charleston.

RIVER COMPANIES.

Coosaw Company, Coosaw river.
Farmers' Company, Coosaw river.
Oak Point Mining Company, Bull river.
South Carolina Phosphate Company, limited, Beaufort.
Phosphate Mining Company, limited, Beaufort.
Campbell & Wilson, Beaufort.
J. B. & J. Seabrook, Beaufort.
W. T. Seward, Beaufort.
George Gage, Beaufort.
Baring mine, Jacksonborough.
J. G. Taylor, Beaufort.
S. M. Croft, Beaufort.
G. T. Davis, Beaufort.
W. W. Farr, Beaufort.
Trenholm & Venning, Charleston.
Sea Island Chemical Company, Saint Helena sound.
Hume Bros. & Co., limited, Saint Helena sound.

Manufacture.—Numerous advantages are offered to the producer of phosphate rock for converting his product directly into the usual form in which it is applied as a fertilizer, namely, "superphosphate of lime" (see page 815), and thus save freight on fertilizers which would otherwise be shipped from States farther north. The manufacture is increasing rapidly, and the following firms in South Carolina are now making fertilizers of various grades:

List of manufacturers of superphosphates and fertilizers in South Carolina.

Name.	Capital.	Location.
Wando Phosphate Company	$100,000	Ashley river.
Atlantic Phosphate Company	200,000	Do.
Stono Phosphate Company	135,000	Do.
Pacific Guano Company	1,000,000	Do.
Edisto Phosphate Company	200,000	Cooper river.
Etiwan Phosphate Company	300,000	Do.
Ashepoo Phosphate Company	125,000	Ashley river.
Charleston Phosphate Company	50,000	Ashley river.
C. C. Pinckney Company	100,000	Do.
H. Bulwinkle Company	50,000	Do.
Wilcox, Gibbes & Co	100,000	Charleston.
Woodstock Lime Company	100,000	Woodstock.
Domestic Fertilizer Company	50,000	Columbia.
Sea Island Chemical Company	100,000	Beaufort.
Hume Bros. & Co., limited	500,000	Do.
Port Royal Fertilizer Company	125,000	Do.

Statement of manufactured fertilizers shipped from Charleston since 1871.

[Calendar years.]

By—	1871.	1872.	1873.	1874.	1875.	1876.	1877.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
South Carolina railway:							
January	3,616	7,224	8,832	7,330	4,830	8,084	5,480
February	4,809	8,304	10,295	7,901	9,780	11,156	12,419
March	5,763	9,925	13,714	8,214	11,156	8,491	10,710
April	2,853	2,845	5,419	2,949	4,313	2,565	2,183
May	80	112	175	318	164	77	70
Northeastern railroad:							
January	182	626	1,912	1,271	2,872	2,064	385
February	599	1,955	2,008	2,684	3,813	3,894	1,981
March	603	1,284	3,011	2,804	3,195	2,927	3,385
April	293	580	1,606	1,001	1,379	1,109	888
May	....	....	76	41	106	58	57
Charleston and Savannah railway:							
January	4	193	95	116	282	206	322
February	87	587	350	285	497	551	791
March	300	240	520	253	424	401	256
April	54	130	120	153	90	108	26
May	2	1	1	1	1	1	31
Georgetown, Pee Dee, Santee, and Edisto steamers:							
January to June	1,236	2,713	2,038	1,679	1,906	855	1,081
Total five months	20,481	36,719	50,172	37,000	44,808	42,547	40,065
For remainder of year	2,108	1,040	6,126	9,382	6,029	3,896	5,691
Grand total	22,589	37,759	56,298	46,382	50,837	46,443	45,756

Statement of manufactured fertilizers shipped from Charleston since 1871—Continued.

By—	1878.	1879.	1880.	1881.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*	*Short tons.*
South Carolina railway:							
January	6, 789	6, 559	17, 449	14, 930	18, 391	17, 721	21, 443
February	12, 662	14, 445	17, 368	18, 523	19, 837	32, 618	29, 171
March	15, 019	12, 044	10, 814	18, 721	12, 107	21, 626	18, 118
April	1, 795	2, 513	2, 761	3, 599	1, 711	2, 971	5, 019
May	44	53	707	189	548	720	441
Northeastern railroad:							
January	879	285	1, 381	2, 186	2, 424	5, 430	5, 194
February	1, 817	3, 231	3, 366	3, 256	5, 362	9, 708	12, 318
March	3, 371	2, 731	3, 382	4, 939	7, 285	9, 091	7, 822
April	1, 579	634	977	3, 044	955	1, 638	2, 413
May	141	48	201	28	198	216	220
Charleston and Savannah railway:							
January	676	1, 016	1, 102	951	690	2, 059	4, 196
February	584	1, 791	1, 249	1, 155	1, 272	2, 888	5, 373
May	436	1, 444	476	2, 375	594	1, 003	3, 525
April	95	675	203	629	100	225	1, 234
May	2	5	9	50	14	33	20
Georgetown, Pee Dee, Santee, and Edisto steamers:							
January to June	1, 263	1, 364	2, 560	2, 950	2, 002	3, 517	6, 309
Total five months	47, 152	48, 838	64, 005	77, 525	73, 490	111, 464	122, 816
For remainder of year	4, 848	11, 162	15, 995	25, 000	29, 000	20, 000	17, 184
Grand total	52, 000	60, 000	80, 000	102, 525	102, 490	131, 464	140, 000

NORTH CAROLINA.

Within the years which this report is intended to cover (1883 and 1884) discovery has been made of beds of phosphate rock in North Carolina of such extent that they must inevitably become an important factor in the phosphate industry of the United States. The discovery is due to Dr. Charles W. Dabney, jr., director of the agricultural experiment station of North Carolina, and it is from the reports of this institution that the following account has been condensed. The beds of marl common in Virginia are also found in many counties of North Carolina. It has been known for many years that coprolites and fish teeth may be found at the bottom of this marl. They are mixed with shells and rounded pebbles of quartz. They have been noticed occasionally in such quantity that suggestions have been made in several geological reports as to their practical value for fertilizers, but they have remained untouched until now, although the associated marl has been dug for manuring adjacent land. This was the state of knowledge in regard to them from 1852 to 1883. In the winter of 1883 Dr. T. D. Hogg took a phosphatic specimen to the experiment station at Raleigh for examination. The specimen came from a farm at Castle Haynes, New Hanover county. It was followed by another specimen from the same county, near Rocky Point. Both consisted of a "conglomerate" in which phosphatic nodules, sharks' teeth, shells, etc., were bound together by a cement of carbonate of lime. Soon after this Mr. Levi Moore and Col. A. M. Faison sent samples from another part of the State, Sampson county, which bore more the character of phosphate rock. Brief explorations of these localities were made and so much interest was awakened that many samples were sent to the station for analysis. The results showed that numerous deposits of phosphate rock exist in Sampson, Duplin, and Onslow counties. This information was obtained in the first year after the earliest intimation had been received of the existence of the phosphate rock. In January, 1884, a surveying party was sent out, and the following account of its operations gives the basis upon which the subsequent opinion as to the practical value of the North Carolina phosphates is based. The phosphate localities lie in a belt 15 to 20 miles wide, extending from the South Carolina line northeastward with the trend of the coast to the Neuse river, and with its southeastern boundary 20 to 25 miles from the coast line. It runs through the counties of Columbus, Bladen, Sampson, a corner of Pender, through Duplin, and includes a small part of Lenoir, Jones, and Onslow counties. It was the work of the first survey party to establish these limits by examining all the deposits and forming a crude estimate of the situation of each bed as well as the quality and quantity of phosphate. Phosphates were found in one hundred and forty-eight localities in the whole belt. Up to October, 1884, seventy-one of these, lying in the central part of the belt, mainly in Sampson and Duplin counties, had been explored. The boundaries of each bed were determined by digging pits at short intervals. The thickness of the beds and the distance from the surface were measured, and the yield of rock compared with the amount of earth which must be removed to get to it. This exploration developed the fact that the belt is a gently undulating country 60 to 120 feet above the sea-level. The beds are of very irregular outline and in what are usually termed "pockets." They are found on small streams, usually a few hundred feet down the stream from the marl beds. They lie in the bottoms and extend into the adjoining slopes. They are found at all depths from the surface to 20 feet, which is as deep as the exploration has been pushed. The surface soil is a very sandy loam, the subsoil a stiff yellowish or reddish clay. The phosphate rock is found frequently immediately underneath a stratum of 2 to 4 feet of this clay imbedded in coarse sand. Underneath this is another stiff, fine-grained, bluish clay. The layer of phosphate rock is 6 to 20 inches thick. The rock is in the form of light gray to dark greenish-black lumps, which are rounded and perforated, though less so than the South Carolina rock. They vary in size from that of an orange to great slabs or cakes weighing half a ton. The seventy-one beds explored lie along the line of the Wilmington and Weldon railroad, on either side in an area seven miles square, including Warsaw, Bowden's station, and Faison's. Fifty of the beds, varying in size from one-third acre to 12 acres, were found to yield phosphate rock containing from 30 to 60 per cent. bone phosphate, and when followed only to a depth of 10 feet yielded 100 to 1,100 tons per acre, the average being 407 tons to the acre. As this gives the average of the total area explored it does not represent the best yield which would be obtained in mining, by neglecting poor beds. The following is a summary of the survey's work·

Summary of explorations of North Carolina phosphate deposits.

Total number of acres explored	124.98
Total number of pits dug	790
Total cubic feet earth excavated	69,719
Total pounds phosphate rock excavated	75,495
Total calculated number tons of phosphate rock in the 124.98 acres	50,864.48
Average tons per acre	406.98

In order to test the actual cost of mining the rock a bed was selected not for its richness but proximity to the railroad, and the cost involved in loading 50 tons of rock on the cars was carefully noted, as follows:

Cost of mining 50 *tons of North Carolina phosphate rock.*

Cubic yards earth, etc., excavated	681
Fraction of an acre excavated	0.11
Cost of excavation	$110 05
Cost of hauling	33 75
Cost of loading on cars	2 75
Cost of ditching	18 75
Total cost	165 30

This experimental mining was carried on during very wet weather in March, and it is probable that the expense could be reduced to $110 instead of $165. The following are analyses selected at random from among a large number published by the agricultural station:

Analyses of North Carolina phosphate rock.

Locality.	Moisture.	Sand and insoluble matter.	Carbonate of lime.	Phosphate of lime.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Farm of J. W. Best, near Warsaw, Duplin county	1.08	42.96	4.18	42.46
Farm of D. I. Woodward, near Warsaw, Duplin county	.66	30.44	6.30	53.03
Farm of D. I. Woodward, near Warsaw, Duplin county	.39	36.59	6.30	45.78
Farm of R. Middleton, 2 miles east of Warsaw, Duplin county	1.57	38.09	3.81	45.16
Farm of R. Middleton, 2 miles east of Warsaw, Duplin county	.92	28.92	2.43	57.18
Farm of G. Middleton, 2 miles east of Warsaw, Duplin county	1.73	59.47	3.12	28.19
Farm of G. Middleton, 2 miles east of Warsaw, Duplin county	1.79	51.17	5.91	37.28
Farm of Levi Moore, 4½ miles southeast of Warsaw, Duplin county	.63	37.36	4.96	44.51
Farm of Mrs. R. Bowden, 1½ miles west of Warsaw, Sampson county	....	60.58	3.43	28.88
Farm of Col. A. M. Faison, 2½ miles west of Warsaw, Sampson county	....	39.60	3.01	46.56
Farm of A. Rich, 3 miles south of Faison's, Sampson county	....	34.60	5.71	46.19
Capt. L. T. Hicks, 4 miles southwest of Faison's, Sampson county	....	35.76	5.11	43.58

These analyses show that the composition varies within considerable limits, but also that beds can be picked out which will yield phosphates as rich as those of South Carolina. They contain small amounts of calcium fluoride, oxides of iron, and alumina.

As to the chance of this rock being utilized, there is nothing in the location of the beds which would interfere with its being mined for local use in the manufacture of superphosphates. The beds are all comparatively near the Wilmington and Weldon railroad, and the test of the cost of mining has shown that rock can be put on the cars at a price low enough for the profitable manufacture of superphosphates. Considering the enormous amount of manufactured phosphates used in North Carolina, it is safe to predict that factories will soon be established to satisfy the needs of the State by home products. At present phosphates are not manufactured to any great extent in North Carolina except at the works of the Navassa Phosphate Company, near Wilmington; this company is so removed from the phosphate region and has become so well connected with other sources of phosphate rock that it must be looked upon rather as a foreign element, and if the new beds are to be utilized it must be by manufacturers located nearer the deposits and working in common with the miners. Such home manufacture will have the advantage of minimum freights for crude material as well as manufactured fertilizers. In regard to the possible influence of the North Carolina phosphates upon the fertilizer trade at large, it must be remembered that the question of exportation brings up the sharpest competition with the Charleston phosphates. If phosphates can be shipped from North Carolina which contain as much calcium phosphate as those of South Carolina, the competition comes upon an even footing, and that phosphate will find sale which can be delivered at least cost. The superior facilities for loading on vessels at Charleston would probably be sufficient to decide in favor of those deposits, which are directly at a deep-water harbor, while the North Carolina phosphates must be mined through woods and swamp land, requiring much improvement in the way of terminal facilities. Further, in order to compete with the South Carolina industry, North Carolina must break into well-established lines of trade involving other industries than phosphates. It has still to be shown that the phosphate deposits of North Carolina are so extensive as to become a rival of Charleston in point of quantity. If, however, they should prove equally large, the question of their utilization outside of the State is one of the time when the cost of mining in Charleston shall rise to the limit of profitable shipment in North Carolina.

The "conglomerate" found near Castle Haynes and Rocky Point, in New Hanover county, is a formation different from phosphate rock. It is found at the bottom of marl beds, and consists of cemented coprolites and bones of fish. Taken as a whole, the composition of the conglomerate is given in the following analysis:

Analysis of North Carolina coprolitic marl.

	Per cent.
Calcium carbonate	64.26
Calcium phosphate (bone phosphate)	11.16
Magnesia	.81
Potash	.40
Sulphates and clorides	Traces.
Sand, soluble silica, oxide of iron, alumina, etc., undetermined	23.37
	100.00

The conglomerate is found "in large beds along the northeast Cape Fear river, in Pender and New Hanover counties. The beds are seen wherever the creeks have cut through the sand or wherever ditches have been dug, throughout a region 25 miles long and 10 miles wide. Beginning at the south, they appear at various points about Wilmington; 1 mile east, at a ballast quarry, whence a lean phosphatic rock has been shipped to many parts of the world as ballast; 2 miles northeast, along the banks of Smith's creek; 1½ miles east, in S. W. Noble's marl pits. From this point the beds extend up the northeast Cape Fear, appearing chiefly upon the right bank of the river, and throughout the country to the east, until they disappear under the sand banks of the coast. Ten miles north of Wilmington, in the Castle Haynes neighborhood, they attain their greatest development and come nearer the surface. They appear all along the bank of the creek here 4 or 5 feet thick, and in the fields adjoining the creek the conglomerate is found within 2 feet of the surface and 4 to 5 feet thick. The beds cross the river 1½ miles north of Castle Haynes, and from this point onward appear chiefly on the west side, between the river and the line of the Wilmington and Weldon railroad. Here again they are seen on the banks of the creek and in the ditches. They are exposed to great advantage on French Brothers' farm, 3 miles east of Rocky Point, where marl and limestone have been largely dug. The Messrs. French have removed the limestone for burning lime down to the conglomerate and exposed it for several acres. To the north from this point the beds are found on Durham farm, the Walker farm, across the river on Gregory's creek, etc., until they are lost in Holly Shelter and Angola Bay swamps. North of the swamps, in Duplin, Onslow, and Jones counties, the phosphates occur again [but now as phosphate rock].

"At French's bed a tough, solid shell-limestone 5 to 7 feet thick is found 3 or 4 feet below the surface; below this the conglomerate is 2 inches to 2 feet thick. At Castle Haynes there is either a mere skim of the limestone or none at all, covering the 4 to 5 feet of conglomerate. At the other places a layer of loose nodules is found on top of the conglomerate. At Noble's farm, near Wilmington, a bed of very soft marl 2 feet thick is found carrying the nodules, and a bed of hard conglomerate under this for 2 feet deeper. At other places, a thick bed of shell marl rests upon the conglomerate." "The nodules of this conglomerate are of all sizes from a pumpkin to a bean. They are smaller about Wilmington and Castle Haynes, and larger at French's. They are of all shapes, but for the most part kidney and egg shaped. Their color is light gray to greenish black. Some are perforated, but less so than South Carolina rock. The composition varies markedly even in the same piece of conglomerate." The following is the complete analysis of one of the nodules from the conglomerate, taken at random:

Analysis of North Carolina phosphatic nodules.

	Per cent.
Sand	43.66
Carbonate of lime	34.56
Magnesia	.86
Potash	.39
Oxide of iron and alumina	.56
Phosphate of lime	19.99
Sulphuric acid	Trace.
Chlorine	Trace.
	100.02

"The variations in composition of the nodules from different localities, and even from the same locality, are illustrated by the following analyses:

Comparative analyses of North Carolina phosphatic nodules.

		Sand and insoluble matter.	Carbonate of lime.	Phosphate of lime.
		Per cent.	*Per cent.*	*Per cent.*
From Castle Haynes	1	22.07	42.12	20.50
	2	33.52	20.45	33.97
	3			30.90
From French's farm	1	18.50	39.04	25.34
	2	20.02	42.12	22.68
From Noble's farm	1	3.25	51.34	31.59
	2	31.66	15.94	42.09

"The average percentage of phosphate of lime in a large number of individual nodules, separately examined, is 32. A large lot of nodules ground up together and well mixed gave 30.90 per cent. phosphate of lime. The economic relations and agricultural value of these deposits were tested this year (1884) with such good results that a company, called the North Carolina Phosphate Company, has been formed to put this material on the market. The conglomerate is very easily mined. After the 2 feet of earth is removed with plows and scrapers, the deposit is shattered with powder, crushed, and ground." The deposits are on navigable water and will probably be profitable.

FLORIDA.

Phosphate rock has been found in Florida, in Clay, Alachua, Duval, and Gadsden counties, and between Wakulla and the Saint Mark's river in Wakulla county. Lately a large deposit of phosphatic nodules has been reported by Dr. Willliam Dall as occurring in the central portion of the State, in the neighborhood of Gainesville; it is supposed to extend across to the northwestern border. Attention has only recently been called to it, and a small mill has just been started at Hawthorn, Alachua county, 6 or 7 miles from Gainesville. Bowlders of phosphate rock have been found on knolls further east than Hawthorn. The deposit is a fine sand to a coarse gravel coated by phosphate of lime, and has often an oölitic appearance. The deposit is said to rest on the Oligocene. In places the beds are 6 to 8 feet thick. It is very probable that the cost of freighting phosphates from Charleston to distant points in Florida will tend to make these deposits a valuable source of superphosphates for local use.

ALABAMA.

BY W. C. STUBBS.

In Alabama there is a belt running across the State from east to west, just below its middle, included between parallels of latitude 32° and 33°, which has a widespread celebrity. Locally it is known as the "black belt," formerly so called because of its prevailing black lands, so productive of corn and cotton. Latterly it is referred to politically as the "black belt" on account of the predominance in numbers of the negro race, outnumbering the whites nearly four times. In fact one-half the negroes in Alabama are to be found in this belt. Agriculturally this belt is called "the prairies," because here and there, where the Rotten Limestone comes to the surface, occur patches of true prairies, and from their presence, and the similarity of most of the soils, the term "prairie" is applied to this entire region. Geologically this belt belongs to the Cretaceous or Chalk period. The great chalk hills of England, characteristic of this period there, are replaced in Alabama by the Rotten Limestone. This formation is divided by Hilgard, in his geological report of Mississippi, into four groups: First or lowest, Eutaw; second, Tombigby Sand; third, Rotten Limestone; and fourth, Ripley. The four groups are thus described by him:

"I. *Eutaw group.*—Bluish black or reddish laminated clays, often lignitic, alternating with and usually overlaid by non-effervescent sands, mostly (though not always) poor in mica and of a grayish yellow tint. Contains beds of lignite, very rarely other fosssils. Those found (by Tuomey in Alabama, none in Mississippi) are silicified, and the sand when indurated shows a siliceous cement." The name Eutaw was applied to this group by Dr. Hilgard because at Eutaw, Alabama, characteristic beds of this portion of the Cretaceous period occur, which were first examined and recognized by Tuomey.

"II. *Tombigbee Sand group.*—Sharp, strongly micaceous sands of greenish blue, laminated when indurated, and cemented by carbonate of lime. Very unequally developed in different localities, and apparently subordinate to the Rotten Limestone, into which it shows many lithological transitions and many of whose fossils it shares.

"III *Rotten Limestone group.*—Soft, chalky, white limestone, of great uniformity and thickness, passing into heavy, calcareous, massy clays or light-colored marls.

"IV. *Ripley group.*—Hard, crystalline, white limestones (generally somewhat sandy, and often glauconitic), underlaid by black or blue micaceous marls, whose fossils are in an admirable state of preservation. These strata form the Pontotoc ridge in Mississippi, and the Chunnennugga ridge in southeastern Alabama; according to late researches by Conrad, they also exist at Eufala, Alabama."

In the report of the Geological Survey of Alabama for 1881 and 1882, Dr. E. A. Smith makes only three divisions of the Cretaceous period in Alabama. Either the Tombigbee Sand does not exist or, if existing, without characteristic differences, it is blended with the others. He thus describes them:

"I. *Eutaw group.*—Consists largely of clays and sands, which are for the most part deeply covered with beds of Stratified Drift.

"II. *Rotten Limestone group.*—This is a great thickness of an impure argillaceous limestone, interstratified with clays. The disintegration of these beds give rise to the true prairie soils.

"III. *Ripley group.*—Consists of hard, sandy limestone, sometimes crystalline, underlaid by strata of bluish micaceous marls."

The Eutaw group in Alabama is present in great thickness, but is everywhere covered with drift and loam to such an extent as to render difficult the task of tracing its boundaries. The Rotten Limestone is well developed, being over 1,000 feet in thickness, and underlying many thousand square miles of the State. The Ripley group, while running nearly across the State, finds its best development in southeastern Alabama.

It is in this "black belt," this Cretaceous formation, these "prairies," that phosphates have been recently found. If a line be drawn from Columbus, Georgia, westward through Tuskegee, Montgomery, Marion, Greensborough, and Eutaw, Alabama, on to Columbus, Mississippi, we shall have very nearly the northern boundary. It extends southward from this line for twenty to fifty miles. Geologically, it is bounded on the north by the Stratified Drift, which conceals the line of union between it and the coal fields; and on the south by the Lower Tertiary groups.

The phosphatic deposits occur at the base and summit of the Rotten Limestone, and they may be designated as the northern or lower belt and the southern or upper belt.

The northern or lower belt.—This extends across the State, near the northern limit of the Cretaceous formation previously described. The State Geological Survey has traced it from Wetumpka westward through Prattville, Mulberry, Selma, Hamburg, Greensborough, Choctaw Bluff, Eutaw, Pleasant Ridge, and Pickensville; and Mr. LeRoy Brown, jr., assistant State chemist, has traced it eastward through Tuskegee, Society Hill, and Marvyn. In the eastern part of the State it is covered by the Drift to such a depth as to be practically useless; yet its existence is revealed by hundreds of wells and several creeks which have passed through the overlying Drift into the underlying greensand. In the central and western part of the State this belt is well exposed. On the farm of Mr. J. W. Spencer (who was the first person to suspect the true character of these phosphates, and through whose instrumentality the public were informed of their existence), near Hamburg, in Perry county, a thorough examination of these beds was made by Mr. D. W. Langdon, jr., of the State Geological Survey, and Mr. Brown. The beds were found to outcrop not only on his place, but also on the farms of Messrs. A. F. and A. J. Davis, near the Cahaba river, and 5 miles from Hamburgh. The following is a section of the formation on the places of Messrs. Davis, and is similar to that occurring at many other places in the State which have been examined:

	Feet.
Rotten Limestone, increasing in depth to the south	
Greensand marl	0 to 6
Soft cream-colored rock, bearing phosphoric acid and some nodules	½
Gray limestone, bearing phosphatic nodules	1 to ½
Indurated ledge	1 to 1½
Yellow micaceous sand, upper part shelly	10 to 20
Ferruginous sand	10 to 20
Indurated ledge	1 to 1½
Yellow sand, upper part shelly	10
Blue laminated clay	½ to 40
Ferruginous sand	30 to 40
Greensand, composing bed of Cahaba river	4

At the base of the Rotten Limestone occurs a stratum of greensand marl, five to six feet in thickness, which overlies and acts as a guide-seam to the underlying phosphate-bearing rock. This greensand varies greatly in composition, as the analyses to be quoted will show, being more highly phosphatized in depth. In fact, the lowest portions of this greensand contain a few phosphatic nodules, which increase in quantity as the underlying matrix rock is approached. The occasional presence of these nodules in the greensand analyzed doubtless occasioned the discrepancies in the analytical results.

Underneath the greensand occurs a sandy, indurated nodular rock, in many places cream-colored on top and gray at bottom, 2 feet thick, cemented by carbonate of lime, which contains the phosphatic nodules. Some idea of the proportion of phosphatic nodules in this rock may be formed from the experiments made by Messrs. Langdon and Brown. Several pits were sunk through this stratum, and samples were taken; these were accurately measured, then broken into small pieces, and the nodules carefully collected and weighed, with the following results:

Proportion of phosphatic nodules in matrix, and estimated yield per acre.

	Depth from surface at which sample was taken.	Thickness of green-sand marl.	Thickness of phosphate rock.	Size of sample taken for getting nodules.	Weight of nodules extracted.	Yield per acre.	Average.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Ozs.*	*Tons.*	
Pit I	68	48	24	3 by 3 by 1¼	5½	574.8	377.92
Pit II	9½	....	24	12 by 12 by 3	72	261.4	
Pit II	18	....	24	12 by 12 by 1	6	208	
Pit II	25	....	24	6 by 6 by 2	4	261.4	
Pit II	33	....	24	6 by 6 by 2	12	784	

From these estimates the matrix rock, 2 feet thick, yields from 208 to 784 tons per acre, and should an economical process for separating the nodules from the rock be devised, the supply of the former would be adequate for manufacturing. Where this rock is exposed on the surface, phosphatic nodules are found in quantity. The rock is easily decomposed by atmospheric agencies; and the nodules thus released remain in place, by virtue of their greater specific gravity, while the lighter matrix is washed away. Accordingly, along this shore line we find nodules of all sizes, from that of an egg to that of a pea, and of every conceivable shape. They vary in color from white to nearly black, and when rubbed together emit a peculiar petroleum odor. These nodules are mainly phosphate of lime, with small quantities of other ingredients, mostly carbonate of lime. Accompanying them are casts or molds of fossils, which are also highly phosphatic. "Teeth of sharks" and "bones of saurians" occur also in large quantities.

Directly under the matrix rock is an indurated ledge, from 6 to 18 inches in thickness, containing a small quantity of phosphoric acid. Below this occur beds of yellow micaceous sands, ferruginous sands, indurated ledge, blue clay, etc., until we reach another bed of greensand, which forms the bed of the Cahaba river. Analyses of carefully-selected samples show phosphoric acid in these rocks. The entire section appears to be more or less phosphatic. This phosphatic material may be classified under three heads, namely:

1. Highly phosphatic nodules and casts.
2. Phosphatic greensands.
3. Yellow, micaceous, and other sands, indurated ledge, etc.

The first are highly phosphatic, containing from 20 to 38 per cent. of phosphoric acid, equivalent to from 43 to 83 per cent. of bone phosphate of lime. The second class contain from 0.5 to 12 per cent. of phosphoric acid, equivalent to from 1 to 26 per cent. of bone phosphate of lime, besides much potash. The third class contain only a small percentage of phosphoric acid, and except for local use are of no value agriculturally.

Analyses of samples of each, with localities and descriptions, are appended:

Analyses of phosphatic nodules and casts.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Lime.	Where analyzed.
1	Nodules from Spencer's, Hamburg, Alabama.	....	22.02	48.00	....	University of Alabama.
2	Phosphatized shell, Spencer's, Hamburg, Alabama.	....	19.80	43.16	....	Do.
3	Surface nodules, Spencer's, Hamburg, Alabama.	....	38.00	82.84	....	Do.
4	......do	....	35.5	77.39	....	Do.
5	......do	....	25.66	55.88	....	Do.
6	Surface nodules, Selma, Alabama	....	26.1	56.90	....	Do.
7	......do	....	25.8	56.24	....	Do.
8	......do	....	36.00	78.48	....	Do.
9	......do	....	38.00	82.84	....	Do.
10	Surface nodules, Prattville, Alabama	....	28.14	61.34	....	Do.
11	......do	....	32.00	69.76	....	Do.
12	Surface nodules, Davis's, Hamburg, Alabama.	20.50	19.41	42.37	40.20	State laboratory of A. and M. College.
13	Surface nodules, Spencer's, Hamburg, Alabama.	1.09	26.13	57.04	....	Do.
14	Black nodules, Spencer's, Hamburg, Alabama.	2.50	24.16	52.03	....	Do.
15	White nodules, Spencer's, Hamburg, Alabama.	21.94	20.07	43.81	....	Do.
16	Mixed nodules, Spencer's, Hamburg, Alabama.	9.79	19.97	43.59	49.36	Do.
17	Nodules separated from matrix rock	22.07	14.02	30.60	39.03	Do.
18	Phosphate rock, Marion, Alabama	7.61	11.05	24.12	....	Do.
19	Phosphate nodules, Eutaw, Alabama	21.99	16.48	35.97	34.51	Do.
20	Bone fossil, Barker's Mill, Alabama	39.71	14.93	32.59	18.40	Do.
21	Phosphatic nodules, Marion, Alabama	25.94	26.74	58.37	33.55	Do.
22	Nodules from stratum overlying greensand.	2.67	25.59	55.85	....	Do.
23	Fossil casts and nodules, Selma, Alabama.	6.49	24.85	54.25	31.57	Do.
24	......do	50.68	12.88	28.11	22.20	Do.
25	Fossil casts and nodules, Turkey Creek, Alabama.	5.93	25.14	54.88	....	Do.
26	Fossil casts, Greensborough, Alabama	16.22	23.20	50.64	39.34	Do.
27	Fossil casts and nodules, Eutaw, Alabama.	9.44	21.53	47.00	41.72	Do.
28	Fossil casts and nodules, Newbern, Alabama.	10.85	23.10	50.43	....	Do.
29	......do	....	....	....	....	Do.
30	Fossil casts and nodules, Day's Bend, Alabama.	7.73	26.54	57.94	....	Do.
31	Fossil casts and nodules, Marion, Alabama.	12.55	14.23	31.06	....	Do.
32	......do	....	....	....	....	Do.
33	Fossil casts and nodules, Pickensville, Alabama.	4.23	22.40	48.90	....	Do.

Analyses of greensands.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Lime.	Where analyzed.
1	Greensand from Spencer's, Hamburg, Alabama.	....	11.41	24.88	....	University of Alabama.
2	......do	....	10.16	22.15	....	Do.
3	......do	....	10.19	22.21	....	Do.
4	......do	....	11.51	24.99	....	Do.
5	......do	....	11.20	24.42	....	Do.
6	......do	....	9.00	19.62	....	Do.
7	......do	....	11.78	25.78	....	Do.
8	......do	....	9.31	20.29	....	Do.
9	......do	....	11.33	24.70	....	Do.
10	......do	....	5.16	11.26	....	Do.

Analyses of greensands—Continued.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Lime.	Where analyzed.
11	Greensand from Spencer's, Hamburg, Alabama.	....	9.97	21.78	....	University of Alabama.
12	......do	....	8.12	17.70	....	Do.
13	......do	....	7.6	16.59	....	Dr. Charles Gibson, Chicago.
14	Greensand, Eutaw, Alabama	....	7.8	17.01	....	University of Alabama.
15	Greensand, Choctaw Bluff, Alabama	....	5.03	10.96	....	Do.
16	Greensand, Coke's Mill, Alabama	....	4.30	9.38	....	Do.
17	Greensand from Spencer's, Hamburg, Alabama.	41.42	67	1.46	29.62	State laboratory of A. and M. College.
18	......do	41.11	85	1.85	17.68	Do.
19	......do	48.81	4.35	9.56	9.13	Do.
20	......do	28.62	66	1.44	24.80	Do.
21	Greensand, first 12 inches, Pit I, Spencer's, Hamburg, Alabama.	42.66	1.61	3.51	16.18	Do.
22	Greensand, next 9 inches, Pit I, Spencer's, Hamburg, Alabama.	54.52	2.79	6.09	13.86	Do.
23	Greensand, next 7 inches, Pit I, Spencer's, Hamburg, Alabama.	31.95	2.13	4.65	9.44	Do.
24	Greensand, next 20 inches, Pit I, Spencer's, Hamburg, Alabama.	....	3.38	7.37	8.40	Do.
25	Greensand, western Autauga, Alabama	....	2.49	5.43	8.38	Do.
26	Greensand from a well, western Autauga, Alabama.	....	6.67	14.56	7.57	Do.
27	Greensand bed 3 feet thick, western Autauga, Alabama.	....	2.63	5.74	....	Do.
28	Greensand bed 8 feet thick, Summerfield, Alabama.	....	3.60	7.85	....	Do.
29	Greensand, Selma, Alabama	.....	5.22	11.39	....	Do.
30	Phosphatic greensand, Wetumpka, Alabama.	66.15	1.52	3.31	4.33	Do.
31	Indurated greensand, Eutaw, Alabama	39.87	3.24	7.07	....	Do.
32	Greensand, Marion, Alabama	37.70	3.78	8.25	....	Do.
33	Greensand, Scott's Station, Alabama	....	2.36	5.17	....	Do.

Analyses of the matrix rock.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Lime.	Where analyzed.
1	Matrix of nodules, Spencer's, Hamburg, Alabama.	....	5.12	11.16	....	University of Alabama.
2	......do	....	4.2	9.16	....	Do.
3	......do	....	4.65	10.14	....	Do.
4	......do	....	8.00	17.44	....	Do.
5	Blue matrix of nodules, Spencer's, Hamburg, Alabama.	....	2.2	4.80	....	Do.
6	White matrix of nodules, Spencer's, Hamburg, Alabama.	....	3.6	7.85	....	Dr. Charles Gibson.
7	Matrix of nodules, Selma, Alabama	....	5.05	10.11	....	Do.
8	......do	....	3.98	8.67	....	University of Alabama.
9	Matrix of nodules, Spencer's, Hamburg, Alabama.	30.28	2.58	5.63	30.06	Do.
10	......do	32.50	3.85	8.40	29.61	State laboratory of A. and M. College.
11	Matrix rock free from nodules, Hamburg, Alabama.	40.61	2.45	5.34	27.07	
12	Matrix rock with nodules, Hamburg, Alabama.	53.74	2.79	6.09	17.20	Do.
13	......do	33.81	2.26	4.93	27.85	Do.
14	......do	47.13	1.46	3.18	24.41	Do.
15	Matrix rock free from nodules, Hamburg, Alabama.	27.82	95	2.09	41.00	Do.
16	Matrix rock with nodules	31.55	3.58	7.81	32.07	Do.
17	Matrix rock with nodules, Cahaba river	54.30	1.83	3.99	25.22	Do.
18	Cream-colored matrix with nodules, Hamburg.	35.17	2.20	4.80	24.10	Do.

Analyses of other phosphatic materials in northern belt.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Lime.	Where analyzed.
1	Sands below indurated ledge, Hamburg	......	6.5	14.17	......	University of Alabama.
2	do	......	3.8	8.24	......	Do.
3	Sands under greensand, Cahaba river	94.34	......	......	1.95	State laboratory of A. and M. College.
4	These represent section from greensand downward, each taken 3 feet below the other; Hamburg.	31.53	3.38	7.37	26.73	Do.
5		56.65	69	1.50	21.10	Do.
6		92.3	33	72	9.47	Do.
7		91.89	29	63	2.85	Do.
8		95.55	44	96	72	Do.
9		96.27	11	25	75	Do.
10		92.14	39	85	68	Do.
11		91.40	42	92	79	Do.
12		90.42	25	54	50	Do.
13	Indurated ledge underlying phosphate rock, Hamburg.	53.77	1.16	2.53	23.33	Do.

Phosphatic nodules and casts.—These are sufficiently rich in phosphoric acid to justify their use in the manufacture of acid phosphates. They are fully the equal of the Charleston phosphates in quality, and like the latter contain very small quantities of iron and alumina. Acid phosphates made from them would therefore show but little tendency to "reversion." Several experiments made in the State laboratory have demonstrated their adaptability to the manufacture of acid phosphate. The results of several trials clearly indicate that acid phosphates containing over 14 per cent. of available phosphoric acid can easily be made from the best nodules and casts.

The question of quantity is not so easily decided. Manufacturers have indicated their willingness to remove their works to Alabama as soon as they can have positive assurance of the existence of phosphates of such quality and in such quantities as may be required in a first-class fertilizer factory. Examinations in the field have been far too limited to justify positive assertions in regard to available quantities. Only the nodules can be used for the manufacture of acid phosphates. These are found on the surface of the ground along the shore line, where the matrix rock comes to the surface, entirely across the State. In many places they can be raked up in considerable quantities, and if in every neighborhood a local agent were appointed to purchase these nodules, a large quantity in the aggregate could be accumulated. Again, a demand for these nodules would soon cause many farmers and planters along this belt to make full examination of their lands, and perhaps discover extensive beds which may reasonably be supposed to exist.

Another method of obtaining the nodules has been suggested. The matrix rock containing them consists largely of carbonate of lime—enough, it is believed, to reduce the rock to powder (except the phosphatic nodules) by burning and slaking. After slaking, the lime could be passed through sieves, which would stop the nodules. The lime could possibly be utilized as a cheap fertilizer, since it would still contain a considerable amount of phosphates, and thus reduced it would be available to plants. Kainite might be added where potash is required. The nodules after such treatment are said to be easily ground. The above plan of utilizing such rock was first suggested by Sir John Bennett Lawes to Dr. Charles W. Dabney and others, of North Carolina.

The establishment of acid phosphate works all over the State of Alabama would be of great benefit to her farmers. Acid phosphates, or guano, whose chief constituent is acid phosphate, have been extensively used for some time in the south Atlantic States for growing cotton. Gradually their use has extended into Alabama, and to-day, with the exception of the "black belt" in which the phosphates are found, every portion of the State annually consumes large quantities of commercial fertilizers. This rapid growth of the use of phosphates clearly establishes the want of the soil for phosphoric acid.

With this great and growing demand for acid phosphates so near the beds; with large deposits of pyrites upon the Coosa river easily accessible for the manufacture of sulphuric acid; with railroads and rivers offering facilities for cheap transportation, nothing prevents the immediate erection of scores of mills for the manufacture of commercial fertilizers, save the scarcity of the high-grade phosphates (nodules and casts). Effort will not be wanting in solving this vital question. Already a car or two of these materials have been shipped to Chicago to determine their commercial value, and if found valuable, as doubtless they will be, systematic and persistent search will perhaps reveal sufficient quantities.

Greensands.—While the phosphatic nodules and casts are found in limited quantities, the phosphatic greensands are simply inexhaustible. They form extensive beds, running from Georgia on the east to Mississippi on the west. These beds cross the Cahaba, Tombigbee, Alabama, and Chattahoochee rivers, and are easily reached by several lines of railroads; thus cheap transportation to every part of the State is afforded. They are superior to the New Jersey greensands, since they contain increased quantities of phosphoric acid. Properly utilized they must be a source of immense wealth to the State, and that too at an early day, provided transportation is made sufficiently low, so as to induce extensive experiments with them. Knowing what a wonderful transformation has been wrought in the fertility of the soils of New Jersey by the extensive use of greensands, it is not idle speculation to make the above assertions.

The southern or upper belt.—This belt has the same general direction as the one just described. It runs along the southern border of the "black belt," and geologically occurs at the base of the Ripley group or at the summit of the Rotten Limestone group. This section of the Cretaceous formation is called the "hill prairies," because the topography of the country is broken by alternations of hard and soft strata, the former only remaining, giving in many places steep and precipitous hills. These hard rocks contain a fair percentage of phosphoric acid; here and there are found, besides, casts and nodules yielding phosphoric acid, in quantity and quality similar to those found in the northern belt. Here too we find the rock to be generally phosphatic for some distance below and above the main phosphate-bearing rock. These beds lie south of the northern belt at a distance varying from a few to 50 miles. They are more highly developed and are more accessible in the eastern part of the State than those of the northern belt, which is deeply covered by the Drift. These rocks are very extensive, and though rarely containing over 10 per cent. phosphoric acid, the aggregate contents of this ingredient is very large. Their proximity to the Tertiary lands adjoining them on the south must prove, if properly utilized, of incalculable benefit to the latter. This belt has not been thoroughly examined, and therefore its capabilities are simply conjectural. However, enough is known to give it a high value for local use, and to arouse a hope that richer beds may yet be found beneath its jagged crest. Analyses of samples from the southern belt are appended:

Analyses of phosphatic material from southern belt.

Number.	Description.	Insoluble matter.	Phosphoric acid.	Bone phosphate.	Where analyzed.
1	Phosphatic shell casts, Minter station	10.72	16.90	36.89	State laboratory of A. and M. College.
2	Phosphatic shell casts, Coatopa	9.38	14.56	31.78	Do.
3	Phosphatic shell casts, Livingston	11.65	9.92	21.65	Do.
4	Phosphatic shell casts, Pickensville	4.21	22.40	48.90	Do.
5	Siliceous limestone, Minter station	42.44	1.43	3.12	Do.
6	White argillaceous limestone, Coatopa	25.74	5.01	10.93	Do.
7	Siliceous limestone, Moscow	57.00	.58	1.26	Do.
8	Argillaceous limestone, Livingston	25.30	.56	1.22	Do.
9	Argillaceous and siliceous limestone, Livingston.	53.16	.41	.86	Do.
10	Argillaceous limestone, Livingston	39.52	.50	1.09	Do.
11	Light-colored limestone, Livingston	15.02	.64	1.39	Do.
12	White argillaceous limestone, Livingston	13.30	2.58	5.62	Do.
13	Glauconitic limestone, Richmond	15.73	2.62	5.72	Do.
14	Siliceous limestone, Richmond	34.95	3.21	7.00	Do.
15	......do	40.16	5.94	12.96	Do.
16	......do	39.47	8.69	18.97	Do.
17	Glauconitic limestone, Minter station	17.38	.74	1.62	Do.
18	Hard siliceous limestone, Fort Deposit	....	13.55	29.58	University of Alabama.
19	Siliceous limestone, Strata	....	6.22	13.57	Do.
20	Siliceous limestone, Olustee	41.90	1.14	2.49	State laboratory.

Other occurrences of phosphates.—Other occurrences of phosphates in the Rotten Limestone belt have been mentioned by Dr. Smith in a late report on the phosphates of Alabama, and the opinion is advanced that "phosphatic strata are to be found at intervals through the whole thickness of this rock, being more abundant at the base and summit." The following are analyses, made at the State laboratory, of some casts and nodules taken from between the two belts described and overlying the Rotten Limestone:

Analyses of casts and nodules from between the two belts.

	From near Newbern.	From near Boligee.
	Per cent.	*Per cent.*
Insoluble matter	3.59	2.98
Phosphoric acid	20.68	22.76
Bone phosphate	45.14	49.68

Dr. Smith likens these phosphates, "in geological position, mode of occurrence, and character of material," to the phosphates of Cambridgeshire, England.

Tertiary phosphates.—Since the foregoing was written a letter from Dr. Smith has been published in the Montgomery *Advertiser*, announcing the discovery of "phosphatic material from three distinct horizons, namely, from Nanafalia, from Coffeeville, and from Saint Stephen's. At the two localities first named the specimens are hard secular masses of phosphate of lime, while at Saint Stephen's the nodules are embedded in a phosphatic marl, which Mr. Langdon put at 12 feet in thickness, as exposed above the water at the time of his visit. The marl contains a very considerable percentage of phosphoric acid. This is an important discovery, since it shows that our phosphatic deposits, so far from being confined to the Cretaceous formation, are distributed through at least 1,000 feet of the Tertiary strata; that is, the uppermost or Saint Stephen's marl is at least 1,000 feet above the Nanafalia."

FOREIGN SOURCES.

By David T. Day.

The principal production of crude phosphates in foreign countries is in Norway, Germany, Portugal, and England, the various guano islands on the South American coast, and the Canadian apatite deposits (described briefly on page 805). Germany sends to England about 50,000 tons yearly of phosphorite, which is less pure than the Norwegian apatite. About 40,000 tons of native phosphorite are consumed yearly in Germany. Spain, and particularly Portugal, formerly shipped phosphorite to England to the extent of 12,000 tons yearly; in 1881 the product increased to 44,321 tons. The superphosphates in Belgium are made partly from native phosphates, but the bulk is imported. Russia has an area of more than 30,000 square kilometers, between the Volga and the Desna, where there are large deposits of apatite, containing 15 to 20 per cent. phosphoric acid (=30 to 45 per cent. bone phosphate), and sometimes as high as 29 per cent. phosphoric acid (=60 to 65 per cent. bone phosphate). The locality is traversed by railroads, but has never been explored for agricultural purposes. There are, however, some foreign capitalists who export a certain quantity to England.

Rich phosphate deposits are used for home consumption in Austrian Galicia. They are found principally at Calluz, Tchowtchevka, Minkoretz, and Liadowa. They yield from 50 to 85 per cent. bone phosphate.

Imports.—These countries affect the United States by sharing the export trade to England. The numerous guano islands and Peruvian guano affect this country by direct imports. These imports are, however, frequently from islands controlled by the United States, and do not enter as ordinary imports. The following table shows the imports from these two sources as far as they have been collected by the Bureau of Statistics:

Guano brought from islands, rocks, and keys appertaining to the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Long tons.			*Long tons.*	
1869	15, 622	$253, 545	1877	6, 060	$79, 822
1870	14, 318	356, 830	1878	17, 930	211, 239
1871	14, 154	340, 235	1879	8, 733	95, 137
1872	4, 209	60, 865	1880	12, 795	147, 051
1873	11, 014	161, 690	1881	16, 883	179, 882
1874	6, 877	100, 345	1882	15, 249	160, 016
1875	7, 269	122, 012	1883	7, 873	92, 130
1876	14, 785	192, 972	1884	9, 333	106, 431

Provision is made that the introduction of guano from such islands, etc., shall be regulated as in the coastwise trade between different ports of the United States. This guano, which does not differ essentially in composition from other phosphates, is not included in the statement of imports from foreign countries which follows. It is that form of crude phosphate of lime which is obtained from the islands where it has been deposited as the excrement of sea fowl. It contains a small percentage of ammonia, also, which makes it advantageous to distinguish it by name from the crude phosphates of ordinary origin.

Phosphates imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Guano.		Crude phosphates and other substances used for fertilizing purposes.		Total Value.
	Quantity.	Value.	Quantity.	Value.	
	Long tons.		*Long tons.*		
1868	99, 668	$1, 336, 761	....	$88, 864	$1, 425, 625
1869	13, 480	217, 004	....	61, 529	278, 533
1870	47, 747	1, 414, 872	....	90, 817	1, 505, 689
1871	94, 344	3, 313, 914	....	165, 703	3, 479, 617
1872	15, 279	423, 322	....	83, 342	506, 664
1873	6, 755	167, 711	....	218, 110	385, 821
1874	10, 767	261, 085	....	243, 467	504, 552
1875	23, 925	539, 808	....	212, 118	751, 926
1876	19, 384	710, 135	....	164, 849	874, 984
1877	25, 580	873, 459	....	195, 875	1, 069, 334
1878	23, 122	849, 607	....	285, 089	1, 134, 696
1879	17, 704	634, 546	....	223, 283	857, 829
1880	8, 619	108, 733	....	317, 068	425, 801
1881	23, 452	399, 552	....	918, 835	1, 318, 387
1882	46, 699	854, 463	133, 955. 50	1, 437, 442	2, 291, 905
1883	25, 187	537, 080	96, 585. 86	798, 116	1, 335, 196
1884	28, 090	588, 033	16, 542. 00	237, 594	825, 627

PHOSPHORUS FROM IRON SLAG.

Nearly all grades of iron ores contain traces of phosphorus which it is necessary to remove in making good iron; after this removal the phosphorus is found in the form of phosphates in the slag. In 1882, G. Rocour, of Luttich, Germany, proposed to obtain phosphoric acid from blast-furnace slag, for use in fertilizers, by fusing the slag in a reducing furnace so as to obtain a metallic mass rich in phosphides; these yield phosphureted hydrogen on treatment with sulphuric acid, and this is converted into phosphoric acid by simple means. In 1883 the method was modified by heating the slag in a reducing furnace and fusing the result with 3 to 7 parts of anhydrous sodium sulphate to 1 of phosphorus. By this process the greater part of the phosphorus is converted into sodium phosphate, which is then dissolved out in water. The insoluble residue contains the calcium, iron, and manganese of the slag, and after all the phosphorus has been extracted by a second fusion it is smelted for the iron. Another process, patented by C. Scheibler in 1884, appears more practicable and has just come into use on the large scale in Schalke and Stolberg. The slag, which must be highly basic, is roasted in a Siemens furnace, and then treated with steam, by which the lime in the slag is slaked, reducing the whole to an impalpable powder. By stirring with water the lime is removed as milk of lime, while the heavier phosphates sink and are afterwards treated with just enough hydrochloric acid to combine with the earths in combination with silicic and phosphoric acids. By carefully regulating the dilution of the hydrochloric acid it is possible in a few minutes to obtain a solution of phosphoric and silicic acids containing only small quantities of iron and manganese compounds. By fractional precipitation with the lime water prepared in the first part of the process, calcium bi-phosphate is obtained containing 35 to 37 per cent. phosphoric acid. It seems probable that this source of phosphorus will be profitable. Eleven patents have been taken out in the United States for utilizing the phosphorus in slag, but it is not known that any are in actual use.

APATITE.

The beds of apatite irregularly distributed through the New England States were formerly mined for making superphosphates. Since the development of the South Carolina phosphate rock native apatite has not been mined. The Canadian deposits continue to furnish all of this mineral used in the United States.

There are two districts in Canada which contain deposits of economic value. One of these is in the province of Ontario, and includes parts of the counties of Lanark, Leeds, and Frontenac; while the other is in the province of Quebec, chiefly in Ottawa county. The mines of the north Ottawa phosphate region are on the Rivière aux Lièvres, about 18 miles above Buckingham, a station on the Canadian Pacific railroad, east of Ottawa. The mineral occurs here in veins which vary in thickness from 2 to 30 feet, and is found in both massive and crystalline forms. The deposit is about 8 miles long and nearly as wide, running northeast through Templeton, Wakefield, Portland, and Buckingham townships. In this region the Lièvre Phosphate Company has land following the Lièvre river, and reports apatite also in Bowman township. Other mines are those of the Dominion Phosphate Company; Mr. Allen's Little Rapids mine in Portland East; the Union Phosphate Company's mine, and the Emerald mine at High Rock. All these companies are actively engaged in mining apatite. In the Ontario region mining is active at Otter lake, near the town of Perth, Lanark county. The apatite is found in well-defined veins or lodes, 3 to 8 feet wide, occasionally cropping out on the surface, and extending to an unknown depth. One thousand eight hundred and twenty-two acres have been reserved for mining; part of this (639 acres) is freehold property, the remainder being mineral concessions held under mineral rights from the government of the Dominion of Canada in perpetuity. Three hundred prospect shafts, varying in depth from a few feet to 100 feet, have been sunk in various parts of the field; the veins are found to increase in width with the depth. At the bottom of the deepest shaft the vein was 8 feet wide.

Apatite consists of tri-calcium phosphate, together with varying amounts of calcium chloride and calcium fluoride; its value for superphosphates depends not only upon the percentage of phosphoric acid, but also upon the amount of calcium fluoride, because of the injurious hydrofluoric acid to which this substance gives rise on treatment with sulphuric acid. Canadian apatite is of a very high grade, as will appear from the following comparison with European apatites, and is one of the valuable mineral resources of the Dominion:

Analyses of foreign apatite and phosphorite.

From—	Percentage of tri-basic phosphate of lime.
Arendal, Norway	92.189
Greiner, Tyrol	92.160
Murcia, Spain	92.066
Tokovaia, Ural	91.668
Studianka, Russia	91.646
Ottawa (mean of seven analyses)	87.521
Estramadura, Spain	81.593
Staffel, Nassau	75.273

The total amount mined since 1878 is given below:

Production of Canadian apatite from 1878 *to* 1884 *inclusive.*

Years.	Long tons.
1878	3,701
1879	11,927
1880	7,974
1881	15,601
1882	17,181
1883	17,840
1884	22,143

It is evident that the industry is increasing rapidly. The output for 1884 would have been greater except that very wet weather stopped the transportation from the mines to Montreal in October. About 2,500 tons were therefore collected at the mines, and not included in the above statement. The cost of mining is about $5 or $6 per ton. The selling price is not proportional to the percentage; that is to say, is not constant per unit of bone phosphate, but the unit value increases with the percentage. Thus, 45 to 50 per cent. apatite has a unit value of 17 cents, but guaranteed 85 per cent. is worth 35 cents per unit or $30 per ton.

The larger portion of the apatite mined in Canada is shipped to England, where the amount received is greater than from any other source of phosphates, except the South Carolina phosphates and the guano islands. Some is also shipped to the Continent, and a small quantity is imported into the United States for use in the New England superphosphate works. The following table gives the disposition of the yield of 1884:

Shipments of apatite from Canada in 1884.

To—	Long tons.
Liverpool	8,557
London	4,389
Glasgow	3,043
Hamburg	2,970
Bristol	1,824
Dublin	210
Penarth, for orders	100
Sunderland	60
Bristol Channel	50
United States	200
Consumed in Canada	700
Total	22,103

The only rival of Canadian apatite in the English market is that from Norway, which is very pure, but occurs in very narrow veins, and only 700 tons are exported each year.

No deposits of apatite of any economic value are reported to have been discovered in the United States during the years 1883 and 1884. A specimen of apatite from near Amelia Court House, Virginia, where the mineral occurs sparingly in association with mica, fluorspar, beryl, etc., in a coarse granite, contains, according to an analysis by Mr. H. Rowan:

	Per cent.
Lime	53.94
Alumina	.19
Ferric oxide	.81
Phosphoric oxide	41.06
Fluorine	3.30
Chlorine	Trace.
Loss by ignition	.81
Insoluble residue	.63
	100.74

MARLS.

By F. A. Wilber.

In the "Mineral Resources of the United States, 1882," pages 522 to 524, will be found as complete a list of the localities in the eastern division where marl occurs as could then be given. There have been few developments of new localities since that report was prepared. The only deposits of importance opened during this time have been those of the phosphatic marls of Alabama. These have been reported on by Prof. E. A. Smith, State geologist, and, although still undeveloped, are reported to be very valuable. The marl is said to contain an unusual percentage of phosphoric acid. Prof. W. C. Stubbs has described these deposits on page 794 *et seq.* of this volume.

The only other notices of beds of marl recently opened are from the regions named in the report mentioned above. None of them are of sufficient importance to demand particular mention.

The use of marls as fertilizers has greatly diminished in New Jersey, which is the only State in which marls are employed for this purpose to any extent. The increased use throughout the State of commercial fertilizers has been accompanied by a corresponding diminution in the amount of marl dug and used, even in the marl districts. Much less has been shipped to the surrounding regions. Competent authorities report that the amount used in the State during 1883 fell considerably below the amount reported for 1882 (1,080,000 short tons, valued at $540,000 at the pits). It is estimated that 10 per cent. less (or 972,000 short tons) were mined in New Jersey in 1883; and that a further falling off reduced the amount mined in 1884 to about 875,000 short tons. These estimates are confessedly rough, since no actual statistics of production can be given for the State; nor can the amounts used in any of the other States which have deposits be obtained, owing to the large number of scattered deposits which are worked in a desultory manner.

The fact that many of these marls contain potassium salts, sometimes 3 to 4 per cent., has perhaps not received the attention which it demands, when the scarcity of potassium sources in this country is considered.

GYPSUM.

BY F. A. WILBER.

Eastern division.—There are no additions to be made to the list of localities in which gypsum occurs, given in the "Mineral Resources of the United States, 1882," pages 526 and 527. The localities there mentioned are in the States of Michigan, Ohio, New York, Virginia, Alabama, Louisiana, Texas, Arkansas, Iowa, and Kansas.

The only States producing any large amounts of gypsum are Michigan and Ohio. In addition to that manufactured in these States, from minerals mined in them, a large quantity of stone is imported from Nova Scotia, which is ground and distributed among the States on the Atlantic seaboard. Mr. Henry S. Sproull, commercial editor of the *Real Estate Record and Guide*, of New York City, makes the following statement in regard to the amount of gypsum passing through the port of New York during 1883 and 1884: "The production of plaster in the Atlantic States (Maine to Virginia) in 1883 amounted to an aggregate of 130,000 tons of 2,240 pounds each, about 95 per cent. passing through the hands of operators in this city, from whom my information is derived. The above total has varied very slightly for two or three years; but is probably 10,000 tons in excess of that of 1880 and 1881. Its division is about 60,000 tons calcined and barreled for regular trade consumption, and the balance is simply ground and distributed for fertilizing purposes. The receipts of stone are entirely from Nova Scotia. The estimated production of plaster for the Atlantic States during 1884 is 115,000 long tons, exclusive of the Maine product, the local manufacturers still handling about 95 per cent. of the amount. The division of the product is about 60,000 tons for fertilizing purposes and 55,000 tons calcined and barreled for trade use. The shrinkage as compared with 1883 is entirely in the calcined product, which has lost ground as a fireproofing material consequent upon the introduction of fireclay brick as a competitor. The weight of a barrel of plaster is 250 pounds net. The average price per barrel in 1883 was \$1.32½, and in 1884 \$1.25. The average price of Nova Scotia gypsum laid down at New York in 1883 was \$3.25 and in 1884 \$2.85 per long ton. The points in the United States where Nova Scotia stone is ground and calcined are New York City, Newburg (New York), and Newark (New Jersey); and constitute the local manufacturing interest above referred to. A small amount of domestic quarried stone, estimated at 10,000 tons annually, is burned and ground in Maine."

According to the report of the inspector of mines the production of gypsum in Nova Scotia in 1883 was 144,668 long tons. In 1882 the production of gypsum in Great Britain was 101,872 long tons, valued at £58,145; in 1883 it was 99,551 long tons, valued at £43,215.

The following table gives the quantities and average values of the total imports of gypsum imported into the United States during the period from 1877 to 1884, through the port of New York, and the average price of calcined plaster during the same period:

Amounts of unground gypsum entered at the port of New York during the years 1877 *to* 1884 *inclusive, and average prices per ton January* 1; *also price of calcined plaster per barrel.*

Years.	Tons.	White lump, per ton.	Blue lump, per ton.	Calcined plaster, per barrel.
1877	48, 833	$3 00	$2 75 to 3 00	$1 25 to 1 50
1878	42, 575	3 00	2 75 to 2 80	1 15 to 1 25
1879	44, 031	2 80	2 75	1 00 to 1 15
1880	60, 952	3 25 to 3 50	3 00 to 3 25	1 00 to 1 15
1881	60, 236	3 00 to 3 25	2 75 to 3 00	1 20 to 1 25
1882	77, 463	3 75 to 4 00	3 00 to 3 25	1 30 to 1 40
1883	104, 542	3 00	3 00 to 3 25	1 30 to 1 35
1884	99, 144	3 00	2 75	1 30 to 1 35

During the same period there were exported from the port of New York packages of calcined plaster as follows:

Exports of plaster from the port of New York, 1877 *to* 1884 *inclusive.*

Years.	Packages.	Value.
1877	17, 083	$26, 040
1878	17, 257	23, 073
1879	11, 732	14, 902
1880	11, 191	15, 321
1881	17, 391	$24, 419
1882	25, 765	38, 025
1883	18, 085	25, 713
1884	21, 491	30, 372

There has been a slight falling off in the general trade in New York during 1884, the greatest loss being in the output for fireproofing purposes. Prices did fairly well and were tolerably firm until toward fall, when a decline in all grades took place. The export trade was fully as good as usual. The trade in lump plaster at this point was lighter than in former years, less going to local manufacturers and more up the Hudson river. The use of plaster for fertilizing purposes has been greater than during 1883.

The production of Michigan is given in the following tables:

Amount of land plaster and calcined plaster produced in Michigan.

Years.	Land plaster, short tons.	Stucco, barrels of 300 pounds.
Land plaster, previous to 1866	100, 000	
1866	14, 604	
1867	17, 439	
Stucco, previous to 1868		[a]80, 000
1868	28, 837	34, 966
1869	29, 996	41, 187
1870	31, 437	46, 179
1871	41, 126	48, 685
1872	43, 536	59, 767
1873	44, 972	82, 453
1874	39, 126	82, 449
1875	27, 019	61, 120
1876	[a]39, 131	64, 386
1877	[a]40, 000	[a]55, 000
1878	40, 000	48, 346
1879	43, 658	50, 800
1880	49, 570	106, 004
1881	33, 178	112, 813
1882	37, 821	135, 165
1883. At Grand Rapids	53, 930	138, 600
1883. In Iosco County	[b]6, 152	[b]20, 500
Total	761, 532	1, 268, 420

[a] Partly estimated.

[b] The total amount produced in Iosco county for 1883 was 9,227 tons. The exact division of this amount between land plaster and stucco is not known, but is estimated as above by Mr. Swineford.

Amount of land plaster and calcined plaster produced by the several plaster companies in Michigan during the years stated.

	Land plaster, short tons.				Stucco, barrels of 300 pounds.		
	1879.	1880.	1881.	1882.	1880.	1881.	1882.
Godfrey & Brother (*a*)	9, 117	9, 000	6, 422	6, 080	23, 000	27, 500	30, 274
Grand Rapids Plaster Company (*a*)	8, 970	12, 000	6, 375	7, 512	23, 500	20, 400	32, 854
George H. White & Co. (*a*)	1, 900	....	......	....	....	....	....
Wyoming Mills Company (*b*)	7, 000	10, 000	6, 093	6, 901	....	....	9, 643
Union Mills Company (*b*)	4, 500	7, 500	6, 716	8, 298	35, 000	34, 913	23, 074
Taylor & McRingolds (*b*)	10, 585	9, 570	6, 572	6, 037	24, 504	30, 000	27, 993
Smith, Bullard & Co. (*e*)	1, 586	1, 500	1, 000	2. 993	....	....	11, 817
Total	43, 658	49, 570	33, 178	37, 821	106, 004	112, 813	135, 655

a Quarry at Grand Rapids. *b* Quarry at Grandville. *c* Quarry at Alabaster.

In 1883 the several manufacturers in Michigan produced plaster as follows:

	Short tons.
Grand Rapids Plaster Company	9, 843
F. Godfrey & Brother	9, 968
Noble & Co	8, 716
Union Mills Plaster Company	8, 698
Loren Day	7, 483
Alabastine Company	9, 415
B. F. Smith	9, 227
Total	63, 340

This total includes both land plaster and stucco. All the above manufacturers are located at Grand Rapids and vicinity, except B. F. Smith (East Tawas, Iosco county). The product of the Grand Rapids companies is divided as follows:

Stucco (barrels of 300 pounds)	138, 600
Land plaster (tons)	34, 130
Total tons	53, 930

The production of Ohio is given by Mr. George A. Marsh, of Marsh & Co., Sandusky. This firm is the only one manufacturing plaster in that State. The works are at Sandusky and Gypsum, and the quarries are at Gypsum.

Production of stucco and land plaster in Ohio.

Years.	Stucco.			Land plaster.		
	Barrels.	Average price per barrel.	Total value.	Short tons.	Average price per ton.	Total value.
1881	12, 409	$1 55	$19, 234	3, 705	$4 35	$16, 117
1882	16, 388	1 46	24, 656	4, 404	4 33	19, 069
1883	20, 919	1 41	29, 496	4, 678	4 15	19, 414
1884	*a*20, 307	1 38	28, 024	4, 217	4 09	17, 248

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a Of this amount, 16,907 barrels were made up to October 15; the remainder, 3,400 barrels, being estimated.

Rocky Mountain division.—In "Mineral Resources of the United States, 1882," pages 528 and 529, will be found mention of the localities in Colorado, Montana, and New Mexico containing deposits of gypsum. No additions to the localities mentioned there have been reported during 1884. This mineral occurs abundantly in Utah. Deposits are found near Cedar City, in Iron county; at Salt Creek, or Nephi, Juab county; at White Mountain station, 12 miles southwest of Fillmore, Beaver county, and on the Muddy, in San Pete county. No development of any of these deposits is reported. In Dakota, according to Mr. F. F. Chisolm, "gypsum occurs all around the Black Hills in limited beds, and some plaster-of-paris is made at Spearfish, Crook City, Sturgis, and Rapid City, from the beds near each place. At Rapid City the amount manufactured in 1884 was about 15,000 pounds. No plaster-of-paris is used in the Black Hills except that manufactured there.

Plaster-of-paris made by the mill at Colorado Springs, Colorado, during the years 1879 *to* 1884 *inclusive.*

Years.	Sacks of 100 pounds.	Pounds.
1879	3,000	300,000
1880	8,100	810,000
1881	9,600	960,000
1882	10,350	1,035,000
1883	11,336	1,133,600
1884	8,506	850,600
Total for six years	50,892	5,089,200

"The markets of New Mexico, Colorado, and Wyoming are largely supplied with plaster from these works. The capacity of the mill is three times as great as the supply needed in Colorado. The demand in 1884 was considerably less than that in 1883. The average price charged for this plaster at the mill is 85 cents per 100 pounds, but the amount manufactured in excess of the demand is estimated to be worth less than 10 cents per sack. In addition to plaster-of-paris this company, which is now styled the Colorado Stucco and Cement Company, also manufactured, in 1884, 42,000 pounds of ground gypsum."

Pacific division.—Since the publication of the last report very extensive and apparently valuable beds of gypsum have been discovered in California. The greater part of these beds are located on the Casmalia rancho, in Santa Barbara county, and, being in close proximity to the Morito chute (a coast landing) and other landings, can be delivered in San Francisco and at other ports on the coast at small cost. These deposits, which are of the white or Nova Scotia variety, are represented to be so extensive that they cannot for a long time be exhausted or even sensibly depleted by any drafts likely to be made upon them. Further discoveries of gypsum have been made of late in Los Angeles county and other parts of California, warranting the inference that there will be no deficiency of this mineral in that State, although future requirements will probably be large. Its utility as an aid to agriculture in the arid regions west of the Rocky Mountains having become fully apparent, its employment for such purposes must ultimately reach large proportions.

The other California localities where this mineral is known to occur in notable quantities are the following: along the Truckee pass, Nevada county; near Hill's Ferry, Stanislaus county; on Posa creek, Kern county; in the mountains of the Arroyo Grande, San Luis Obispo county; along Cariso creek, San Diego county; and at different places in Monterey, Ventura, and Tulare counties.

The varieties of gypsum known as alabaster, selenite, and satin spar are found in many places in California; the former abundantly at Arroyo Grande, San Luis Obispo county, and at Point Sal, in Santa Barbara county; selenite in large slabs at Soledad cañon, Los Angeles county; near Dos Palmas station on the Southern Pacific railroad, San Diego county; on Robinson's ranch, Lake county; in the San Emigdio antimony mine, Kern county; and near the town of Gilroy, Santa Clara county. Satin spar occurs plentifully on the Casmalia lands; also at White river, Tulare county; in the Calico district in San Bernardino county, and elsewhere in the State.

Besides the land plaster now beginning to be applied quite freely in California, a good deal is used in the arts and for building purposes, as is shown by the following tables of imports at San Francisco during the past ten years, imports for the last months of 1884 being estimated:

Imports of plaster at San Francisco.

Years.	Barrels.	Years.	Barrels.
1875	22,782	1880	3,200
1876	14,918	1881	5,850
1877	14,487	1882	4,777
1878	11,038	1883	6,300
1879	5,400	1884	5,700

The diminished importation of plaster during late years has been due to the establishment of mills in the State for grinding the gypsum and preparing portions of it for building purposes or manufacturing it into plaster-of-paris, an industry largely carried on at the works of Lucas & Co., in San Francisco, the raw material used by this firm being obtained from the Casmalia rancho, above mentioned. Plaster sells in San Francisco at about the following rates, wholesale: Common, $2.75; casting, $3; superfine, $4.50, per barrel.

The deposits in Nevada and Arizona were noticed in "Mineral Resources, 1882," pages 529 and 530. Nothing further is reported for 1884.

Gypsum imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

[Long tons and hundredweights, of 2,240 and 112 pounds respectively.]

Fiscal years ending June 30—	Ground or calcined.		Unground.		Manufactured plaster-of-paris.	Total.
	Quantity.	Value.	Quantity.	Value.		
	Tons.		*Cwts.*			
1867		$29,895				$29,895
1868		33,988	1,753,881	$80,362		114,350
1869		52,238	2,740,785	133,430	$844	186,512
1870		46,872	2,144,733	100,416	1,432	148,720
1871		64,465	2,008,010	88,256	1,292	154,013
1872		66,418	1,906,787	99,902	2,553	168,873
1873		35,628	2,378,520	122,495	7,336	165,459
1874		36,410	2,474,350	130,172	4,319	170,901
1875		52,155	1,875,440	115,664	3,277	171,096
1876		47,588	2,794,263	127,084	4,398	179,070
1877		49,445	1,953,120	105,629	7,843	162,917
1878		33,496	1,784,774	100,102	6,989	140,587
1879		18,339	1,939,259	99,027	8,176	125,542
1880		17,074	2.406,540	120,642	12,693	150,409
1881		24,915	2,572,140	128,107	18,702	171,724
1882	5,737.14	53,478	2,567,740	127,067	20,377	200,922
1883	4,291.34	44,118	3,157,020	152,982	21,869	218,969
1884	4,996.25	42,904	3,326,200	168,000	(*a*)	210,904

a Not specified.

Alabaster and spar ornaments imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1867	$26,129	1876	$18,323
1868	27,891	1877	16,000
1869	21,564	1878	8,148
1870	22,982	1879	7,986
1871	47,633	1880	9,730
1872	23,108	1881	19,078
1873	22,011	1882	34,292
1874	16,463	1883	23,179
1875	16,185	1884	38,982

Uses.—The mineral is used in two different forms of preparation: (1) as land or ground plaster, unburned; (2) as plaster-of-paris or stucco, ground and burned. There is also a small amount of the massive mineral used for the manufacture of ornamental articles, which are turned from it. The mineral is usually however too soft and friable to be valuable for such purposes.

Land plaster has among others the following applications, of which its largest use is an agricultural one: Manufacturers of artificial fertilizers consume large amounts of it in weighting their products, while its absorbent properties enable them by its use to improve the mechanical condition of the other constituents of the fertilizers. It is also largely used as an adulterating material for the cheaper grades of flour, for coloring materials under the name of terra alba (see "Mineral Paints"), and for various chemical preparations. It has some use in the manufacture of ammonium sulphate from ammonium carbonate, and it is employed as a cement for repairing.

Plaster-of-paris is used for a great variety of purposes. Among numerous others the following are mentioned: It is used as a filling for fireproofing purposes; and as the material for making molds in the manufacture of many articles. Potters make the molds for their white and porcelain ware from it, and makers of terra cotta employ it for a similar purpose. The molds used in making elbows, curves, etc., in the sewer-pipe manufacture are made from it. It is used for taking casts of natural objects and works of art, for sculptors' models, lay figures, etc. Surgeons employ it to confine the parts of a broken limb, and dentists to take casts of the mouth for false teeth. It is largely used in plastering walls and ceilings; as an ingredient in alabastine, which is a preparation for finishing interior house walls; and in making cornices and other work of interior house decoration. It is one of the ingredients of blackboard crayons; it is used as a cement in various manufactures; and, mixed with infusorial earth, as an absorbent for drying purposes. It is sometimes used by miners and quarrymen as a material for tamping blasts, and for this use its great advantage is that no tamping bar is needed and consequently there is little danger of premature explosions. It is added, in small quantities, to light wines in order to retard fermentation and prevent them from becoming acid; and is also added to strong wines to absorb the water that they contain and thus increase the amount of alcohol in them.

MANUFACTURED FERTILIZERS.

By David T. Day.

Character.—Fertilizers include those substances which are added to the soil to supply some needed constituent, and also those substances added for the purpose of rendering available some constituent already present in the soil; that is, bring it into such a condition that it may be assimilated by plants. The number of substances which thus come under the name of fertilizers is almost indefinitely great, for it has become proverbial that when the products of any industry have passed their last stage of usefulness in the various applications of which they are capable they are finally returned to the earth, "used as fertilizers." All these substances are commonly grouped in classes according to the constituent which they are intended to supply to the soil or render available for plants. Nitrogen in the form of ammonium salts, nitrogenous organic matter or nitrates, phosphorus, as salts of phosphoric acid, and salts of potassium and calcium, are the chief substances which must be returned to the earth in place of what is taken out by growing plants. Lime, sodium sulphate, and sodium carbonate are among the important substances used to convert potassium salts and certain other constituents into an available form.

The sources of phosphorus have been stated in connection with phosphate rock. Bones are also used as a source of phosphorus and nitrogen. They contain ordinarily from 40 to 55 per cent. tri-calcium phosphate and 5 to 7 per cent. ammonia.

Sources of nitrogen.—A large part of the "sulphate of ammonia" of commerce is used to furnish nitrogen to the soil. It is made largely from the ammoniacal liquor of the gas works. The production of this substance is increasing rapidly, but in many places the ammoniacal liquor is still allowed to go to waste. Sodium nitrate or "Chili saltpeter" is imported for use as a fertilizer, as well as for the manufacture of sulphuric acid. It also occurs on the Pacific coast of the United States. A large portion of the nitrogen in fertilizers is introduced in the form of nitrogenous organic matter. The variety of forms in which this occurs as various waste products is one reason for the great number of substances called fertilizers. Dried blood, tankage, "azotin," cracklings, "nitrogen A. A.," etc., are some of the forms obtained from slaughter houses and associated factories. Fish, beef, or pork "scrap" is the name given to the bodies of animals from which the oily or fatty portion has been removed for making soap. This scrap is used in large quantities for fertilizers. Dried fish is another much-used source of ammonia. Castor pomace, linseed cake, cottonseed meal, etc., from the oil mills; hoof and horn shavings, hair, leather scrap, and wool waste from the tanneries, wool, and other factories, contain nitrogen in considerable amounts, but it is very differently available. Cottonseed meal, tankage, blood, dried fish, and similar substances yield their nitrogen to plants quite easily, but leather scrap, wool waste, and "shoddy" give up their nitrogen only very slowly, and hence have a very low agricultural value. All of these substances are valued according to the amount of nitrogen contained or its equivalent in ammonia.

Sources of potassium.—The potassium which is added to American soil is at present procured entirely outside of this country. The deposits of kainite at Stassfurt, Germany, and Kalusz in Galicia, are the most important sources of potassium. This kainite is a mixture of the sulphates of potassium and magnesium and chloride of magnesium. Where it is found in purest condition the substance has such a constant composition that it may be represented by the formula $K_2SO_4+MgSO_4+MgCl_2+6H_2O$. The crude mineral as obtained from the mines is shipped for use as a fertilizer without purification. In this form it contains such impurities as sodium chloride, calcium sulphate, etc., as indicated by the following analyses:

Average composition of crude kainite from Kalusz, Galicia.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Potassium sulphate	20.3	19.6
Magnesium sulphate	14.2	14.2
Magnesium chloride	11.1	11.1
Sodium chloride	27.2	27.5
Calcium sulphate	2.8	.5
Insoluble (clay, sand)	9.2	9.8
Water	15.2	17.3
	100.0	100.0

The kainite imported into the United States contains a higher percentage of potassium sulphate, due to careful selection. It is usually sold with a guarantee that it will yield 24 per cent. potassium sulphate. The following is an average sample:

Analysis of kainite imported as a fertilizer.

	Per cent.
Potassium sulphate	24.80
Magnesium sulphate	14.30
Magnesium chloride	12.62
Sodium chloride	32.00
Water	14.36
Insoluble matter	1.92
	100.00

The only method of purification of this substance before use as a fertilizer is that it is sometimes washed with water, thus partially removing the very soluble magnesium chloride, which is generally regarded as an objectionable substance in fertilizers. The imports of kainite during the fiscal years 1881, 1882, and 1883 made up nearly the whole of the following table, that from countries other than Germany being chiefly reshipments:

Values of fertilizers (not elsewhere enumerated) imported free of duty into the United States during the fiscal years 1881, 1882, *and* 1883.

Countries from which imported.	1881.	1882.	1883.	Customs districts into which imported.	1881.	1882.	1883.
Germany	$553, 176	$637, 611	$616, 067	Baltimore	$197, 473	$275, 653	$176, 790
England	185, 600	574, 837	135, 550	Boston	27	15, 596	132
Ireland	105, 016	27, 290	....	New Orleans	5, 337	13, 128	18, 274
Canada	44, 514	20, 580	6, 761	New York	269, 124	394, 247	206, 669
British West Indies	16, 826	69, 239	25, 088	Philadelphia	44, 136	85, 690	81, 528
France	9, 640	25, 307	682	Lake ports	42, 607	15, 378	4, 066
All other countries	205	70, 273	16, 327	All other customs districts	356, 273	625, 445	313, 016
Total	914, 977	1, 425, 137	800, 475	Total	914, 977	1, 425, 137	800, 475

The above table also includes a considerable amount of potassium chloride or "muriate of potash," which is imported from Stassfurt. It does not include the "agricultural salt," of which the following amounts have been imported:

Imports of "agricultural salt" (containing 30 *per cent. or over of potash),* 1869 *to* 1883 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$1, 752	1879	2, 480
1870	9, 698	1880	21, 667
1871	2, 436	1881	8, 187
1874	114	1882	55, 622
1875	1, 867	1883	43, 363

Lime and marl and gypsum or land plaster are added to soil not only to restore the calcium salts removed by plants, but as valuable aids in rendering other constituents, such as potassium salts, available to plants. Sodium sulphate, obtained in this country chiefly in the manufacture of sulphuric acid, is added for the same purpose.

Methods of manufacture.—Nearly all of these fertilizers require a certain amount of preparation before application to the soil. They must be reduced to a very fine condition in order to mix evenly with the soil and act quickly. Simple grinding is the only preparation required for such substances as sodium sulphate, plaster, lime, and the various sources of nitrogen and potassium. Bones are sometimes only ground and sold as bone meal; more frequently they are subjected to the action of superheated steam to drive out the gelatine, which is valuable for other purposes, and the bones are left in a better condition for grinding. Thus the manufacture of fertilizers often consists in nothing but this purely mechanical grinding and steaming process, and perhaps the mixing of several fertilizers together. By far the greater number of fertilizer establishments, however, are designed principally to convert the various forms of phosphates from the insoluble and comparatively valueless condition in which they exist in nature, into a form soluble in water. Phosphoric acid in phosphate rock, bird guano, bones, apatite, etc., is in the form of tri-calcium phosphate, $Ca_3(PO_4)_2$. This substance is very insoluble in water, and, unless ground to an impalpable powder called "floats," is only absorbed very slowly by plants. In order to bring the phosphoric acid into the form of a calcium salt which is soluble in water and hence easily absorbed by plants, the phosphate rock is treated with sulphuric acid, which converts it into an "acid phosphate" or "superphosphate" of lime, in which the phosphoric acid is present as mono-calcium phosphate, $H_4Ca(PO_4)_2$. This substance is soluble in water. The method by which this treatment with sulphuric acid is effected is practically the same all over the world; even the details in the arrangement of the plant are nearly identical throughout the United States.

The phosphate rock when first received is prepared for grinding by drying in a large revolving drum making from twenty to fifty revolutions per minute, through which passes a current of air heated by a furnace. The rock is then crushed to the fineness of sand, and finally reduced to powder by a second set of millstones. The fineness is assured by blowing the powder by a fan through a long tube to the place where it is to be treated with sulphuric acid. The amount of sulphuric acid added to the rock varies, of course, with the exact amount of bone phosphate contained. In England less acid is used than in the United States. It is usual there to treat phosphate rock with about two-thirds its weight of sulphuric acid. In the United States 1,100 pounds Charleston rock is mixed with about 900 pounds of 60 per cent. sulphuric acid (47° Baumé). The mixing takes place in shallow lead pans, 6 to 8 feet in diameter, and the mass is stirred constantly by revolving lead arms. The chief condition of failure or success in the manufacture of superphosphate seems to depend upon the exact conditions under which the mixing of the acid and phosphate takes place. The prime essentials are to add enough sulphuric acid to obtain the maximum amount of soluble phosphoric acid salts; and yet if too much is added the phosphate will not dry; and if, further, the mixing is not skillfully effected, the heat liberated by the action of the acid on the phosphate will not be sufficient to evaporate the moisture before the mass is cold. The superphosphate is next stored in heaps so arranged under drying-sheds that the mass will take many days for cooling, and during this time a requisite amount of moisture will evaporate. This loss of moisture is essential, for, if allowed to remain, its weight would bring the percentage of phosphoric acid below the limit fixed by law. Superphosphate immediately after mixing contains from 24 to 26 per cent. moisture. Under favorable conditions, as for instance exposure to the air and conservation of its initial temperature, there may be a loss of 10 per cent. moisture in 48 hours; but it goes on for one or two months, so that it is a safe rule to follow that acid phosphates which immediately after mixing contain 24 to 26 per cent. moisture will within four weeks dry down to 12 per cent. moisture. The following analyses will serve to show the average composition of acid phosphates 24 to 48 hours after mixing. The analyses were made by Dr. W. B. Phillips, chemist of the Navassa Guano Company, Wilmington, North Carolina, to whom thanks are due for valuable services rendered in the preparation of this paper.

Partial analyses of superphosphate of lime.

	From Navassa rock.	From Charleston rock.
	Per cent.	*Per cent.*
Moisture at 212° Fahrenheit	13.22	13.62
Soluble phosphoric acid	13.92	12.65
Reverted phosphoric acid	1.16	2.07
Available phosphoric acid	15.08	14.72
Insoluble phosphoric acid	.66	1.02
Total phosphoric acid	15.74	15.74

These analyses only account for about 25 per cent. of the entire superphosphate; the rest is made up of calcium sulphate, the oxides of iron and aluminum, sand, and other insoluble matter contained in the crude phosphate.

If a superphosphate is analyzed and then analyzed again a day or two later it will be found that the amount of soluble phosphate is decreasing in proportion to the insoluble phosphate. This change goes on indefinitely, the soluble phosphate reverts to its original condition of insolubility in water; but this reverted phosphate is soluble in a solution of certain organic salts such as ammonium citrate, while the original phosphate is not. It is possible therefore to determine the amount of phosphate which is soluble in water in a superphosphate, and also how much was once soluble, but has "reverted." As this reverted phosphoric acid is so easily soluble in solutions of certain organic salts, it is probably available for plants. Hence the sum of the phosphoric acid soluble and reverted is taken as "available" phosphoric acid in the superphosphate. The nature of this process of reversion has been studied very generally, and is believed to consist in the formation of di-calcium phosphate from tri-calcium and mono-calcium phosphates. The principal circumstances which favor this reversion are the presence of iron and aluminum in the superphosphate, the presence of tri-calcium phosphate, and drying at too high a temperature.

Large quantities of plain superphosphate of lime are sold as a fertilizer. But in order to furnish other ingredients it is usual to mix with it some substance containing nitrogen (fish, beef, or pork scrap, etc.), and a potassium compound (usually kainite), and sell the mixture under the comprehensive term "guano." Many fancy names are also given to the various mixtures, of which new samples are daily brought on the market. No matter what particular names are given them or what particular ingredients are used in their manufacture, their values are fixed by the amount of available phosphoric acid, potassium salts, and ammonia obtainable from them. The table on the next page gives a fair idea of the composition of some prominent mixtures of this kind. The list is copied from the annual report of the North Carolina experiment station for 1884. "The relative valuations are not designed to fix the price at which the article shall be sold. It is impossible to give any one set of figures which shall represent the commercial value of these ingredients over our extended territory and throughout the entire year. The figures merely furnish a convenient method of summing up the results of the analysis and comparing them" (Dabney). "The water given is that lost by continual heating at the temperature of boiling water. The insoluble phosphoric acid is that contained in phosphates which failed to dissolve in neutral ammonium citrate solution, specific gravity 1.09 (Washington method). The soluble phosphoric acid is that free or in the form of phosphates soluble in pure cold water. The 'reverted' is that insoluble in water, but dissolving in neutral standard ammonium citrate solution. This is all that the term reverted signifies here, and it is used simply to stand for the phrase insoluble in pure water, but soluble in standard ammonium citrate solution under the standard conditions. It is generally agreed that it is within the power of plants to take up directly the phosphates so dissolving, or in other words that these phosphates are 'available.' The total available phosphoric acid is simply the sum of the soluble and the reverted acid. Nitrogen is given as such, and also calculated to its equivalent ammonia. Potash is given as K_2O."

Analyses of mixed fertilizers.

Names.	Address of manufacturer or general agent.	Water.	Insoluble phosphoric acid.	Soluble phosphoric acid.	Reverted phosphoric acid.	Total available phosphoric acid.	Nitrogen.	Equivalent to ammonia.	Potash (K_2O).	Relative commercial value per ton 2,000 lbs.
Peruvian guano	Hodgdon and Spencer Company, Norfolk, Virginia.	18. 92	3. 03	3. 98	10. 59	14. 57	7. 27	8. 83	4. 50	$66 95
Soluble Pacific guano for tobacco.	John S. Reese & Co., Baltimore, Maryland.	13. 56	3. 77	6. 51	1. 99	8. 50	3. 13	3. 80	2. 33	33 20
Whann's raw bone superphosphate, plow brand.	Walton, Whann & Co., Wilmington, Delaware.	12. 23	2. 99	6. 15	2. 73	8. 88	2. 64	3. 20	2. 27	31 51
Lister's ammoniated dissolved bone phosphate.	Lister Bros., Newark, New Jersey.	18. 46	1. 07	7. 83	2. 83	10. 66	2. 15	2. 61	2. 61	32 76
Special compound	G. Ober & Sons, Baltimore, Maryland.	17. 50	2 64	8. 66	0. 71	9. 37	3. 64	3. 20	1. 91	31 96
Navassa acid phosphate	Navassa Guano Company, Wilmington, North Carolina.	12. 56	2. 72	7. 87	3. 30	11. 17	...	....	1. 23	21 58
Navassa cotton fertilizer.	......do	15. 17	3. 91	4. 95	3. 93	8. 88	1. 86	2. 26	1. 51	26 84
Orchilla guano	Travers, Snead & Co., Richmond, Virginia.	12. 76	3. 66	....	12. 70	12. 70	....	....	....	22 86
Wando acid phosphate.	Wando Phosphate Company, Charleston, South Carolina.	14. 74	4. 32	8. 56	1. 47	10. 03	....	....	1. 54	19 90
Wando fertilizer	......do	12. 80	4. 91	6. 84	1. 26	8. 10	2. 11	2. 56	1. 56	26 69
Etiwan guano	William C. Bee & Co., Charleston, South Carolina.	16. 14	2. 19	6. 13	1. 91	8. 04	1. 97	2. 39	2. 49	27 02
Edisto acid phosphate	Edisto Phosphate Company, Charleston, South Carolina.	17. 70	1. 96	10. 54	. 81	11. 39	..	....	....	20 51
Good Luck guano	The George W. Miles Company, Milford, Connecticut.	18. 15	4. 83	5. 70	1. 48	7. 18	1. 94	2. 35	1. 62	24 27
Ammoniated soluble Navassa guano.	Navassa Guano Company, Wilmington, North Carolina.	15. 48	4. 62	4. 54	3. 48	8. 02	2. 37	2. 88	1. 26	27 47
Zell's cotton acid phosphate.	P. Zell & Sons, Baltimore, Maryland	15. 15	2. 42	8. 49	2. 04	10. 53	....	....	1. 68	20 97
Soluble Sea Island guano.	Rasin Fertilizer Company, Baltimore, Maryland.	17. 55	4. 30	5. 10	1. 59	6. 69	2. 07	2. 51	1. 81	24 25
Farmer's friend	Read & Co., New York City	12. 99	6. 40	5. 21	3. 83	9. 04	2. 23	2. 71	2. 39	29 38

Legislation regulating the sale of fertilizers.—The use of fertilizers in this country to the extent of $27,000,000 per year testifies to the necessity of returning to the soil the constituents taken from it; and since comparison shows that only one-seventeenth as much is returned to American soil in proportion to the crops harvested as in Germany, it becomes evident that the fertilizer industry must increase greatly in years to come. The conditions of its development deserve, therefore, to be studied as important factors in our national economy. The prime necessity is evidently to establish certain means for distinguishing good fertilizers from those which are inferior. It has been found that chemical analyses alone suffice for this purpose, and accordingly legislation has been resorted to in nearly every State where fertilizers are largely used, to restrict the sale of fertilizers to those which seem valuable. Further, as the farmer is not able to make these analyses for himself, many States have appointed State chemists or have established fertilizer control stations where analyses of all the brands sold in the State are made, and the fertilizers are bought and sold largely upon the basis of the State chemists' valuation. If all the laws were consistent they would doubtless prove more efficient and simple, provided the chemists were also in harmony concerning the results of their analyses. Unfortunately for the industry, neither the analyses nor the laws which regulate the use of their results are satisfactory. As regards the methods of analysis it has been shown that, at least until very lately, the results of analyses of the same sample by two chemists may differ as widely as 3 per cent. in the determination of phosphoric acid, which is usually such an important factor in the valuation of a fertilizer that a difference of 1 per cent. may make a difference of $30,000 per year in the returns of the largest manufacturers. With a view to harmonizing these inconsistent results several conventions have been held by the State chemists, the final outcome of which is a uniform method of analysis; and it is expected that similar movements will lead to uniformity in State legislation. At the first of these conventions, which was held at Washington, in 1880, it became evident that there is little danger of disagreement in the determination of potassium salts or of nitrogen, by which, together with the phosphoric acid, the value of the fertilizer is deduced; but that conflicting results are likely to prevail in the determination of phosphoric acid, particularly in that form known as "reverted" or "citrate-soluble" phosphoric acid. The convention, recognizing that reverted phosphoric acid is not as tangible a substance as could be wished, endeavored to secure better results in the determination by the uniform use of the method most generally recognized as the best at that time. The details of this method, which is that of Fresenius, Neubauer, and Luck, were published in the *Zeitschrift für Analytische Chemie*, Vol. X., page 133. This method, with some slight modifications concerning the temperature at which the extraction with ammonium citrate should be made, has since been known as the "Washington method." It was more generally used than any other, but never by all agricultural chemists on account of its manifestly imperfect results when made to embrace all the conditions in which phosphoric acid must be determined. The desirability of a new method became so evident after the Washington method had been in use for one year, that a second convention was held in Boston as a subsection of the American Association for the Advancement of Science, and five chemists were designated to secure the co-operation and experimental research of agricultural chemists, to collect and examine the various published methods of fertilizer analysis, and to report at the next convention, the whole convention being pledged to assist the committee by conducting any experiments or tests which they might desire. In opening the third meeting of the convention, held at Cincinnati, in August, 1881, Dr. Ledoux called attention to the fact that there had been comparatively little complaint since the Washington meeting in regard to the results obtained in the determination of nitrogen, potash, and total and soluble phosphoric acid; but that in spite of honest endeavor on the part of chemists who attended the previous meetings to adhere strictly to the methods laid down and adopted by the convention, the determinations of insoluble or reverted phosphoric acid had shown the most unfortunate discrepancies. The committee on the establishment of a new method did not report, but in response to a petition presented by the Baltimore Chemical and Fertilizer Exchange, the use of the so called "oxalate method" was substituted for the citrate method for determining reverted phosphoric acid. The difference in the methods consisted in using a solution of 2 grams of ammonium oxalate in 100 cubic centimeters of water, in the place of the solution of ammonium citrate, for effecting the solution of reverted phosphoric acid. The substitution was made because the citrate method did not show the full amount of reverted phosphoric acid in superphosphates containing iron and aluminum. It can hardly be said that this change was in the direction of uniformity, and the ammonium citrate method was returned to at a meeting of agricultural chemists at Atlanta, Georgia, in May, 1884. The return was made in consequence of a paper which had appeared a short time before in the *American Chemical Journal*, in which Professor Gladding showed that the citrate solution dissolves all reverted phosphates, including those of iron and aluminum, at a temperature of 65° C., instead of 40°, as used in the Washington method. It is the opinion of many chemists that this so-called "Atlanta method" represents as much, if not more, progress in the direction of uniformity as has been obtained in any country up to the present, and that further agreement in analytical results will depend upon the exactness with which the minor details are carried out by each analyst. With the view of enforcing the general use of this method, an Association of Official Agricultural Chemists, consisting of analytical chemists connected with departments of agriculture, State agricultural experiment stations, and State boards exercising an official fertilizer control, was organized in Philadelphia in September, 1884. Besides securing uniformity and accuracy in the methods and results of fertilizer analysis, the object of this association is "as far as possible to secure uniformity in legislation with regard to the regulation of the sale of fertilizers in the different States." It seems that the work of such an association must in the future be principally in this last direction.

The greatest impediment to the progress of the industry lies at present in the legislative restrictions which in most States are thrown around the manufacture and sale of fertilizers. It is true that only chemical analysis can determine the valuable article and keep spurious fabrications from being imposed upon the public. But the requirements of the State laws are not confined to establishing merely a healthy control and insisting upon the manufacturer living up to his guaranteed analysis, but harass the trade and farmer alike with unnecessary and in some cases quite absurd provisions.

The average farmer's knowledge of plant physiology and agricultural chemistry is as a rule of a very limited nature. He is not able to determine for himself what are and what are not those essential elements of plant food which he desires to procure for his land by the purchase of fertilizers; for that knowledge lies far beyond the limits of a common school education. Fertilizer control, whether exercised by departments of agriculture or by experiment stations and State boards of agriculture, should therefore serve a double purpose, first, to protect the farmer from imposition, and also to educate him to a proper understanding of the various elements of plant food and their relative value in the soil. To accomplish this it would seem wise to use as far as possible those terms which are most intelligible to the farmer without doing violence to systematic knowledge; but though only three constituents are universally considered as valuable elements in a fertilizer, there are different terms used in almost every State for the expression of phosphoric acid, potassium salts, and ammonia. It is doubtful whether it aids the farmer in making an estimate of the value of a fertilizer to see printed on each bag "phosphoric acid soluble in neutral solution of citrate of ammonia at 100° F." or "anhydrous phosphoric oxide soluble in distilled water," and yet it is made necessary by law not only to brand each bag of fertilizer with a statement of its contents, but the exact form is prescribed and is different in almost every State. The manufacturer, who under heavy penalties is compelled to print exactly these terms on each sack of fertilizer, is thus obliged to use a multiplicity of sacks.

Among the fertilizer manufacturers this subject of legislation has been agitated to the extent of forming a National Fertilizer Association, with headquarters at Baltimore. During the two years of its existence this association has done much toward securing concordant views among the manufacturers concerning advantageous changes in the existing laws which their industry requires. From the hearty indorsement of their efforts by State chemists and commissioners of agriculture this association expects to accomplish much in the direction of the uniform legislation so much desired by both agriculturalist and manufacturer. Already a provisional draft of a uniform law for all the States has been drawn up through the efforts of this association, and it is proposed to present it for the consideration of the Association of Agricultural Chemists at their meeting in Washington in September, 1885.

Production.—Mixed fertilizers are sold in much larger quantities than simple superphosphates and kainite, but the increasing practice of composting or mixing manures on the farm involves increased use of superphosphate, which is added to the compost heap more frequently than directly to the land. The total amount of fertilizers sold in the United States has been computed with great care and labor by Mr. A. de Ghequier, secretary of the National Fertilizer Association. The total amount produced between May 1, 1882, and April 30, 1883, was

877,000 short tons; in 1883–'84 the yield was 967,000 tons; and in 1884–'85 1,023,500 tons. This was produced by the following States:

Estimated production of manufactured fertilizers, years ending April 30.

States.	1883.	1884.	1885.
	Short tons.	*Short tons.*	*Short tons.*
Alabama	3, 000	4, 000	4, 000
Connecticut	15, 000	15, 000	15, 000
Delaware	40, 000	45, 000	50, 000
District of Columbia	7, 000	7, 000	7, 000
Georgia	25, 000	30, 000	35, 000
Illinois	30, 000	35, 000	35, 000
Indiana	3, 000	4, 000	5, 000
Iowa	1, 000	1, 000	1, 000
Kentucky	2, 500	3, 500	4, 000
Louisiana	2, 000	2, 500	3, 000
Maine	6, 500	7, 000	7, 500
Maryland	260, 000	290, 000	300, 000
Massachusetts	75, 000	80, 000	85, 000
Michigan	2, 000	3, 000	3, 000
Missouri	6, 000	6, 000	6, 000
New Jersey	85, 000	90, 000	95, 000
New York	90, 000	95, 000	100, 000
North Carolina	15, 000	15, 000	15, 000
Ohio	15, 000	15, 000	18, 000
Pennsylvania	60, 000	65, 000	70, 000
Rhode Island	12, 000	12, 000	12, 000
South Carolina	90, 000	100, 000	110, 000
Virginia	30, 000	40, 000	40, 000
West Virginia	2, 000	2, 000	3, 000
Total	877, 000	967, 000	1, 023, 500
Value	$23, 680, 000	$26, 110, 000	$27, 640, 000

By obtaining freight lists of the various transportation companies, Mr. de Ghequier has traced the consumption of manufactured fertilizers to the following States:

Estimated consumption of manufactured fertilizers in the following States, years ending April 30.

States.	1883.	1884.
	Short tons.	*Short tons.*
Alabama	45, 000	45, 000
Delaware	10, 000	20, 000
Florida	5, 000	5, 000
Georgia	125, 000	170, 000
Illinois	5, 000	7, 500
Indiana	8, 000	8, 000
Kentucky	6, 000	6, 000
Louisiana	5, 000	5, 000
Maryland	80, 000	75, 000
Michigan	5, 000	5, 000
Mississippi	20, 000	10, 000
Missouri	5, 000	5, 000
New York	30, 000	30, 000
New Jersey	35, 000	40, 000
New England States	60, 000	75, 000
North Carolina	90, 000	95, 000
Ohio	20, 000	20, 000
Pennsylvania	80, 100	100, 000
South Carolina	90, 000	110, 000
Tennessee	10, 000	10, 000
Virginia and West Virginia	80, 000	100, 000
Western States	26, 000	25, 000

Exports.—About 75 per cent. of the phosphate rock mined in the vicinity of Beaufort, South Carolina, is exported, principally to England and Germany. From 5 to 8 per cent. of the Charleston product is also exported to the same markets. Manufactured fertilizers are exported to some extent. The following table gives the record of fertilizers of domestic production exported from the United States, fiscal years 1864 to 1883, inclusive, as furnished by the Bureau of Statistics. In 1884 the exports invoiced as "fertilizers" amounted to 161,352 long tons, valued at $1,096,021. This consisted principally of phosphate rock, with a small amount of manufactured fertilizers.

Fertilizers of domestic production exported from the United States, 1864 *to* 1883 *inclusive.*

Fiscal years ending June 30—	Guano.			Other substances used for manures.
	Quantity.	Value.	Average value.	
	Long tons.			
1864	....	....	....	$40,353
1865	....	....	....	47,896
1866	....	....	....	....
1867	2,203	$25,395	$11.53	28,360
1868	1	228	....	35,404
1869	....	3,220	....	20,508
1870	1,551	61,097	39.39	53,913
1871	1,203	35,000	29.09	264,837
1872	193	11,601	60.11	427,797
1873	258	8,210	31.82	224,084
1874	90	4,325	48.06	279,551
1875	316	9,305	29.45	608,806
1876	156	4,859	31.15	917,362
1877	954	41,530	43.53	1,076,602
1878	161	3,720	23.11	1,208,049
1879	354	8,741	24.69	1,231,841
1880	475	14,891	31.35	588,777
1881	959	29,581	30.85	583,361
1882	681	24,870	36.52	997,499
1883	1,231	52,823	42.91	1,029,678

SALT.

The salt industry of the United States, taken as a whole, can not be said to be in a flourishing condition. Certain large producers, aided by exceptional facilities and by access to market, are still making very fair profits; but many weaker establishments less favorably situated have been compelled to close or to make salt for local consumption only.. The competition is sharp, the great producing districts of Michigan and New York having seriously crowded those of the States in the interior and farther south; while the heavy imports of cheap salt (amounting to $1,690,564 worth in 1884) have an additional depressing effect. When it is considered that the price in 1884 in some districts fell as low as to 63 cents per net barrel at the works, it will be seen how small a margin of profit remains.

Production.—The following table shows the total production in the United States in 1883 and 1884. In it the quantities have been reduced to barrels of 280 pounds, as being the most common unit, though the returns are also reported in bushels of 56 pounds and in tons, the latter unit being generally used where salt is handled in bulk. Stated in other terms, the total output in 1883 would be 1,733,824,680 pounds, or 30,961,155 bushels, or 866,912 short tons of 2,000 pounds; and that of 1884 would be 1,824,182,360 pounds, or 32,574,685 bushels, or 912,091 tons.

Salt product of the United States in 1883 *and* 1884.

	1883.	1884.
	Barrels.	*Barrels.*
Michigan	2, 894, 672	3, 161, 806
New York	1, 619, 486	1, 788, 454
Ohio	350, 000	320, 000
West Virginia	320, 000	310, 000
Louisiana	265, 215	223, 964
California	214, 286	178, 571
Utah	107, 143	114, 285
Nevada	21, 429	17, 857
Illinois, Indiana, Virginia, Tennessee, Kentucky, and other States and Territories, estimated	400, 000	400, 000
Total	6, 192, 231	6, 514, 937

The total apparent yield in 1884 exceeded that of 1883 by 322,706 bushels, but owing to the decline in price the total value was $13,308 less—$4,197,734 in 1884, as against $4,211,042 in 1883. The values given are computed on the basis of net wholesale rates at the point of production. There was, however, a considerable stock of salt on hand in New

York at the close of 1884, made in that year, but not inspected, the production of which will be credited to 1885 when reported by the inspectors. Were this taken into account the total value in 1884 would exceed that of 1883, while the difference in total production would be somewhat greater.

Michigan.—The salt industry of this State has grown to huge proportions. Salt is made in the following counties, arranged in the order of their present productiveness: Saginaw, Bay, Huron, Iosco, Manistee, Saint Clair, Midland, and Gratiot. The supply is derived from brines obtained from borings, and commonly evaporated by artificial heat, for which method the local conditions have been very favorable, the waste from saw mills in the immediate neighborhood of the salt works furnishing an inexpensive fuel in the shape of slabs, sawdust, etc. As the lumber becomes exhausted this advantage will gradually have less weight. A small quantity of salt is still made in Michigan by solar evaporation also. Mr. G. W. Hill, the State salt inspector, has furnished the statistics for the last two years included in the following tables:

Salt made in Michigan, 1880 *to* 1884 *inclusive, by counties.*

[Barrels of 280 pounds each, as in each subsequent reference in this section.]

Counties.	1880.	1881.	1882.	1883.	1884.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Bay	1, 081, 841	1, 107, 617	1, 158, 279	1, 106, 461	1, 110, 445
Gratiot			3, 285	6, 186	3, 500
Huron	256, 841	326, 852	255, 012	256, 965	313, 832
Iosco	147, 800	147, 579	211, 667	210, 644	224, 687
Manistee		1, 642	41, 562	48, 544	123, 033
Midland	41, 462	74, 537	80, 239	66, 135	65, 726
Saginaw	1, 148, 644	1, 083, 990	1, 287, 273	1, 185, 957	1, 245, 912
Saint Clair				4, 780	74, 671
Total	2, 676, 588	2, 742, 217	3, 037, 317	2, 885, 672	3, 161, 806

The following table shows the amount of salt inspected in Michigan since 1869, the first year of the establishment of the State salt inspection, for the years specified:

Grades of salt made in Michigan as reported by the inspectors.

Years.	Fine.	Packer's.	Solar.	Second quality.	Total for each year.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
1869	513, 989	12, 918	15, 264	19, 117	561, 288
1870	568, 326	17, 869	15, 507	19, 650	621, 352
1871	655, 923	14, 677	37, 645	19, 930	728, 175
1872	672, 034	11, 110	21, 461	19, 876	724, 481
1873	746, 702	23, 671	32, 267	20, 706	823, 346
1874	960, 757	20, 090	29, 391	16, 741	1, 026, 979
1875	1, 027, 886	10, 233	24, 336	19, 410	1, 081, 865
1876	1, 402, 410	14, 233	24, 418	21, 668	1, 462, 729
1877	1, 590, 841	20, 389	22, 949	26, 818	1, 660, 997
1878	1, 770, 361	19, 367	33, 541	32, 615	1, 855, 884
1879	1, 997, 350	15, 641	18, 020	27, 029	2, 058, 040
1880	2, 598, 037	16, 691	22, 237	48, 623	2, 685, 588
1881	2, 673, 910	13, 885	9, 683	52, 821	2, 750, 299
1882	2, 928, 542	17, 208	31, 335	60, 222	3, 037, 307
1883	2, 828, 987	15, 424	16, 735	33, 526	2, 894, 672
1884	3, 087, 033	19, 308	16, 957	38, 508	3, 161, 806

Previous to 1869 the salt production of the State was as follows:

Years.	Barrels.	Years.	Barrels.
1860	4,000	1865	477,200
1861	125,000	1866	407,077
1862	243,000	1867	474,721
1863	466,356	1868	555,690
1864	529,073		

The average price which Michigan salt sold for in different years was as follows:

Years.	Price per barrel	Years.	Price per barrel.
1866	$1 80	1876	$1 05
1867	1 77	1877	85
1868	1 85	1878	85
1869	1 58	1879	1 02
1870	1 32	1880	75
1871	1 46	1881	85
1872	1 46	1882	70
1873	1 37	1883	81
1874	1 19	1884	75⅔
1875	1 10		

At the foregoing prices the total spot value of the product was $2,344,684 in 1883, and $2,392,536 in 1884.

In Michigan there are 117 firms engaged in the manufacture of salt, operating 101 steam and 271 pan blocks. There are besides 4,500 covers for the manufacture of solar salt. The total manufacturing capacity of the wells in operation is 3,875,000 barrels.

The process of manufacture has thus been described by a correspondent of a daily paper: "The method of crystallization by 'solar' evaporation, a slow process in that climate, gives a purer product than by artificial heat. By another process the brine is boiled down to salt in large kettles placed in ovens over fire arches. An improvement on this was the pan. The idea of the kettle was evolved, the kettle was flattened out, made large on the bottom, and shallow. This allows more rapid boiling and consequently a speedier crystallization than could be had in the kettles, but the greater heat is full of danger to the salt, as it is apt to take up so much of the impurities in the agitated water as to injure its quality. This method has almost entirely been superseded in Michigan by the 'steam salt block,' in which salt is made entirely by steam heat. A specimen steam block is a building of wood, 208 feet long, 90 feet wide, 16 feet high at eaves, 40 feet high at ventilators, with a chimney-stack rising 10 feet higher. It contains two settlers, each 140 feet long, 9 feet wide and 4 feet deep, together with four grainers, each 150 feet long, 10 feet wide and 18 inches deep. In the settlers and grainers there are immersed in the brine 3,744 feet of four-inch galvanized iron pipe, and the numerous connections necessary to make a working relationship among the pumps, cisterns, settlers, grainers and boilers make a whole of over 9,000 feet of pipe. Under the same roof are fourteen salt-bins and a packing room, adjoining which is the salt-shed, 230 feet long by 150 wide. The brine is limed in the cisterns outside and allowed to stand 48 hours. After becoming clear it is drawn into the settlers inside. There the temperature is raised to 175° Fah., and evaporation goes on until saturation is reached, which takes about 24 hours. It is then drawn into the grainers, the temperature is raised to 185°, and crystallization begins. Every morning the salt is lifted and the grainers refilled. The salt is wheeled into the bins, where it drains 14 days and is then inspected and packed."

New York.—Salt is made on a very large scale in the Onondaga district, at and near Syracuse, which has been steadily productive since the last century. Much attention has been given to the recent discoveries in the Warsaw district, in Wyoming county; and salt is also made on a small scale in Genesee and Livingston counties, at Le Roy, Piffard, and Mount Morris; while very recent strikes have been made at East Gainesville and near Phelps. The total output of the State in 1883 was as follows: Onondaga district, 7,497,431 bushels; other districts, about 600,000 bushels; total, 8,097,431 bushels. In 1884 the production was: Onondaga district, 6,942,270 bushels; other districts, about 2,000,000 bushels; total, 8,942,270 bushels. The figures for 1884 do not include a large stock on hand in the Onondaga district uninspected and unsold. The total spot value of the New York product in 1883 was $680,638, and in 1884 it was $705,978.

The Onondaga salt springs reservation is under State control, the wells being worked on lease. The gross revenue to the State in 1884 was $69,513. The reservation is divided into four subdistricts. Their segregated output in 1884, according to the official returns of Mr. P. J. Brummelkamp, the State superintendent, was:

Salt inspected at the Onondaga salt springs in 1884.

Subdistricts.	Solar.		Fine.		Total.
	Common.	Ground.	Common.	Ground.	
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
1. Syracuse	442, 295	55, 896	883, 644	368, 687	1, 750, 522
2. Salina	388, 449	56, 928	1, 133, 415	334, 452	1, 902, 244
3. Liverpool	624, 654	....	412, 952	....	1, 037, 606
4. Geddes	785, 638	....	1, 118, 718	347, 542	2, 251, 898
Total	2, 241, 036	112, 824	3, 537, 729	1, 050, 681	6, 942, 269

The total production of the Onondaga reservation since 1797, the date of the first leases in lots, has been:

Production of the Onondaga district, 1797 *to* 1884 *inclusive.*

Years.	Solar.	Fine.	Total.
	Bushels of 56 *pounds.*	*Bushels of* 56 *pounds.*	*Bushels of* 56 *pounds.*
1797	...	25, 474	25, 474
1798	...	59, 928	59, 928
1799	...	42, 704	42, 704
1800	...	50, 000	50, 000
1801	...	62, 000	62, 000
1802	...	75, 000	75, 000
1803	...	90, 000	90, 000
1804	...	100, 000	100, 000
1805	...	154, 071	154, 071
1806	...	122, 577	122, 577
1807	...	175, 448	175, 448
1808	...	319, 618	319, 618
1809	...	128, 282	128, 282
1810	...	450, 000	450, 000
1811	...	200, 000	200, 000
1812	...	221, 011	221, 011
1813	...	226, 000	226, 000
1814	...	295, 000	295, 000
1815	...	322, 058	322, 058
1816	...	348, 665	348, 665
1817	...	408, 665	408, 665
1818	...	406, 540	406, 540
1819	...	548, 374	548, 374
1820	...	458, 329	458, 329
1821	...	526, 049	526, 049
1822	...	481, 562	481, 562
1823	...	726, 988	726, 988
1824	...	816, 634	816, 634
1825	...	757, 203	757, 203
1826	...	811, 023	811, 023
1827	...	983, 410	983, 410
1828	...	1, 160, 888	1, 160, 888
1829	...	1, 129, 280	1, 129, 280
1830	...	1, 435, 446	1, 435, 446
1831	...	1, 514, 037	1, 514, 037
1832	...	1, 652, 985	1, 652, 985
1833	...	1, 838, 646	1, 838, 646
1834	...	1, 943, 252	1, 943, 252
1835	...	1, 209, 867	1, 209, 867
1836	...	1, 912, 858	1, 912, 858
1837	...	2, 167, 287	2, 167, 287
1838	...	2, 575, 033	2, 575, 033
1839	...	2, 864, 718	2, 864, 718
1840	...	2, 622, 305	2, 622, 305
1841	220, 247	3, 120, 520	3, 340, 767
1842	163, 021	2, 128, 882	2, 291, 903
1843	318, 105	2, 809, 395	3, 127, 500
1844	332, 418	3, 671, 134	4, 003, 552
1845	353, 455	3, 408, 903	3, 762, 358
1846	331, 705	3, 507, 146	3, 838, 851
1847	262, 879	3, 688, 476	3, 951, 355
1848	342, 497	4, 394, 629	4, 737, 126
1849	377, 735	4, 705, 834	5, 083, 569
1850	374, 732	3, 894, 187	4, 268, 919
1851	378, 967	4, 235, 150	4, 614, 117
1852	633, 595	4, 288, 938	4, 922, 533
1853	577, 947	4, 826, 577	5, 404, 524
1854	734, 474	5, 068, 873	5, 803, 347
1855	498, 124	5, 584, 761	6, 082, 885
1856	709, 391	5, 257, 419	5, 966, 810
1857	481, 280	3, 830, 846	4, 312, 126
1858	1, 514, 554	5, 518, 665	7, 033, 219
1859	1, 345, 022	6, 549, 250	6, 894, 272
1860	1, 462, 565	4, 130, 682	5, 593, 247
1861	1, 884, 697	5, 315, 694	7, 200, 391
1862	1, 983, 022	7, 070, 852	9, 053, 874
1863	1, 437, 656	6, 504, 727	7, 942, 383
1864	1, 971, 122	5, 407, 712	7, 378, 834
1865	1, 886, 760	4, 499, 170	6, 385, 930
1866	1, 978, 183	5, 180, 320	7, 158, 503
1867	2, 271, 892	5, 323, 673	7, 595, 565
1868	2, 027, 490	6, 639, 126	8, 666, 616
1869	1, 857, 942	6, 804, 295	8, 662, 237
1870	2, 487, 691	6, 260, 422	8, 748, 113

Production of the Onondaga district, 1797 *to* 1884 *inclusive*—Continued.

Years.	Solar.	Fine.	Total.
	Bushels of 56 pounds.	*Bushels of 56 pounds.*	*Bushels of 56 pounds.*
1871	2, 464, 464	5, 910, 492	8, 374, 956
1872	1, 882, 604	6, 048, 321	7, 930, 925
1873	1, 691, 359	5, 768, 998	7, 460, 357
1874	1, 667, 368	4, 361, 932	6, 029, 300
1875	2, 655, 955	4, 523, 491	7, 179, 446
1876	2, 308, 679	3, 083, 998	5, 392, 677
1877	2, 525, 335	3, 902, 648	6, 427, 983
1878	2, 788, 754	4, 387, 443	7, 176, 197
1879	2, 957, 744	5, 364, 418	8, 322, 162
1880	2, 516, 485	5, 482, 265	7, 998, 750
1881	3, 011, 461	4, 905, 775	7, 917, 236
1882	3, 032, 447	5, 307, 733	8, 340, 180
1883	2, 444, 374	5, 053, 057	7, 497, 431
1884	2, 353, 860	4, 588, 410	6, 942, 270
Total	64, 500, 057	246, 734, 454	311, 234, 511

The Onondaga wells are from 360 to 420 feet deep, and yield a brine which is evaporated by solar and artificial heat. The solar salt sold in 1883 at an average of 10½ cents per bushel, and in 1884 at 9 cents. The "fine," that is, salt made by artificial heat, brought an average of 7½ cents per bushel in each of these years. Both solar and fine are sold in two sizes, common and ground, making, therefore, four grades.

A table is appended showing the average strength of the brines in degrees of the salinometer (reduced to correspond with a temperature of 60° Fah.) in the years from 1865 to 1884, inclusive, except 1868, for which year there are no records:

Average strength of Onondaga brines.

Years.	Syracuse.	Salina.	Liverpool.	Geddes.	Average.
1865	66. 17	66. 47	60. 65	66. 17	64. 86
1866	65. 90	65. 81	58. 34	65. 90	63. 98
1867	64. 44	64. 35	64. 35	63. 95	64. 27
1869	60. 98	60. 36	60. 36	59. 02	62. 88
1870	59. 49	58. 94	58. 94	59. 34	59. 22
1871	63. 00	62. 35	62. 35	63. 82	62. 88
1872	65. 10	66. 00	67. 00	66. 20	65. 82
1873	63. 43	65. 33	65. 43	67. 52	65. 45
1874	63. 80	66. 15	66. 15	67. 15	65. 81
1875	63. 88	66. 38	66. 38	69. 50	66. 54
1876	66. 75	67. 70	67. 70	69. 33	68. 15
1877	68. 94	69. 19	69. 19	39. 59	69. 26
1878	69. 93	70. 58	70. 58	70. 02	70. 27
1879	66. 61	67. 47	67. 47	67. 16	67. 20
1880	66. 13	67. 10	67. 10	67. 55	66. 97
1881	67. 02	66. 68	66. 68	68. 21	67. 36
1882	67. 75	67. 24	67. 24	68. 63	67. 71
1883	66. 67	68. 30	68. 30	69. 34	68. 63
1884	67. 88	71. 58	71. 58	70. 10	70. 28

The rock salt deposit of the Warsaw valley lies at a depth of from 800 to 2,500 feet, depending upon the locality, the formation dipping 40 feet or more per mile toward the south. The bed is said to have been proved by test wells to be continuous for a distance of 20 miles in a north and south direction. The Warsaw Salt Company sunk the first well in the spring of 1882 and began the manufacture of salt November 22 of the same year. The following description of the method of working is by Prof. C. H. Dann: "The brine comes from a bed of solid rock salt about 80 feet in thickness and about 1,550 feet below the surface. Wells (of which this company has three 5⅝ inches and one 8 inches across) are sunk to the bottom of the salt bed. The well is cased with iron pipe down to the salt. A 2-inch pipe descends to the bottom of the bed, having perforations only for a few feet at the lower end. Pure water from the Warsaw water-works is let into the well between the casing and the small pipe until the well is full. The water in contact with the rock salt dissolves all the salt it will hold, and the brine, being more than twice as heavy as pure water, sinks to the bottom, enters the small pipe, is driven part way up by the weight of the outside column of fresh water, and is pumped into large vats a few feet higher than the evaporating pans. One of the wells is supplied with fresh water from an underground stream. The company has five pans, each 130 feet long by 20 feet wide and 18 inches deep. The full capacity of a pan is 200 barrels a day. The fuel used for evaporating the brine is anthracite coal dust, which costs $1.65 per ton. The brine runs continuously from the vats to the pans, and the salt is constantly depositing in the bottom of the pans and is frequently drawn out with long-handled scrapers upon sloping shelves at the sides of the pans. After draining a while it is taken to large storage bins, where, after drying for two or three weeks, part is put into barrels for shipment, part is shipped in bulk, and part is dried, bolted, and ground for different grades of dairy and table salt. The dryers are two closed cylinders of boiler iron 33 feet long, 6 feet in diameter, traversed by steam pipes, and kept revolving. The salt enters one end of the dryer, passes gradually through it, and issues, dry and warm, from the opposite end. It is then carried by elevators to the third story, whence descending, lumps are taken out by sieves, the salt is bolted, ground, put by women into small sacks, which are thrown into wooden tubes, down which they are carried by their own weight into the packing-room. Three boilers furnish steam for the 80-horse-power Corliss engine and seven smaller engines that propel the drying and grinding machines and the pumps. The buildings cover about three acres, the main building being 520 feet in length."

The following analyses show the character of the artificial brine pumped from the wells:

Analyses of Warsaw brines.

	By F. E. Englehardt.	By W. M. Habirshaw.
	Per cent.	*Per cent.*
Sodium chloride	26.300	25.395
Calcium chloride	.068	.041
Calcium sulphate	.257	.457
Magnesium chloride	.005	.026
Water	73.370	74.081
	100.000	100.000
Specific gravity	1.205	
Saturation		95.

The Warsaw salt is all made by evaporation by artificial heat, no solar salt being produced. A number of grades are made, sold under different trade names, and some salt is sold as a fertilizer, in the shape of "common fine," and known as "agricultural." The following analysis of the Warsaw salt is published by one of the companies:

	Per cent.
Sodium chloride	98.8929
Calcium chloride	.0500
Calcium sulphate	.7230
Moisture	.3341
	100.0000

Prof. J. S. Newberry has published the following account of the geological origin of the New York salt beds: "All the salt deposits of New York apparently occur in one formation, that which has been called for that reason the Onondaga salt group, or, more recently, the Salina formation, a part of the Upper Silurian system. This seems to be the deposit of a great salt lake that occupied central and western New York, northern Pennsylvania, northeastern Ohio, and southern Ontario. Its outlines are not definitely traced, and may have been quite irregular, but probably included an area as great as that of Lake Huron or, perhaps, Lake Superior. In this lake, besides the land wash, which is now represented by the colored shales and marls seen about Syracuse, were deposited great sheets of gypsum and rock salt, and when the water surface was more extended, the impure limestones that form the well-known Water-lime group, from which so much hydraulic cement is made on the Hudson and in central and western New York. About Goderich, Canada, near the northern margin of the old salt lake, rock salt has been found in a number of wells, forming beds from 2 to 65 feet in thickness, interstratified with gypsum and water-lime. At Sandusky, Ohio, near the western border of the old lake, where its sediments are not more than 40 feet in thickness, they include beds of gypsum that are the basis of an important industry. At Syracuse the salt is not obtained directly from the Salina formation, but from brine pumped from wells that penetrate a great mass of sand, gravel, etc., that fills one of the old buried channels formed when the continent stood higher above the ocean than now—before the ice period, when they were to a large extent filled and obliterated—and its surface was deeply scored along the lines of drainage. The old channel at Salina, cutting across the strata, receives the drainage from deeply buried beds of salt, long ago suspected to exist, which have lately been discovered by borings in the country south. Salt being very soluble, rain falling on the surface and penetrating the rocks to these beds of salt has gradually dissolved them to form brine, which, flowing down to a lower level, has filled the reservoir formed by the old channel referred to, and from this has been pumped up and evaporated.

"The salt deposits of the Salina group exhibit an interesting diversity of composition. Some are almost chemically pure, while others contain a large quantity of chloride of calcium, chloride of magnesium, sulphate of magnesia, etc., which constitute the 'bitterns' of the salt-boilers. These differences are apparently the result of different conditions under which the precipitates were made. Salt water contains a great variety of substances held in solution, among which gypsum, common salt, sulphate of soda, sulphate of magnesia, and the chlorides mentioned are the most abundant. When it is evaporated, these salts are thrown down in the inverse order of their solubilities. For example, the sulphate of lime (gypsum) being the least soluble is first deposited; then, when the solution is more concentrated, chloride of sodium and the other salts in order, until finally only the deliquescent salts mentioned are left. These have such affinity for water that they do not exist in nature except in solution, and, after being artificially prepared, rapidly absorb moisture from the atmosphere. These facts give us an explanation of the varying purity of the salt, and the occurrence in certain places of great sheets of gypsum. Where a land-locked basin receives the drainage of the surrounding country—which, although apparently pure water, always contains some salts—by evaporation, the water becomes 'salt,' a characteristic of all undrained lakes, Great Salt lake and the Dead sea being good examples. If such a solution should be further concentrated, the least soluble ingredient, gypsum, would be first thrown down, and a sheet of this might be precipitated while yet all the other saline constituents were held in solution. With further evaporation, a belt or margin of gypsum would be left around the shallower portions of the lake, and chemically pure salt would be deposited when the concentration passed the point of saturation for salt. The diminished waters, now retiring to the deeper parts of the basin, would leave behind them in places sheets of pure salt, while the precipitates subsequently made would contain an abnormal quantity of bitterns. Just such a record we seem to have in the sediments of the old Salina lake, as well as in those of later date in other parts of the world, the salt of certain localities or certain layers being nearly pure, while that of other localities or layers contains an undue proportion of impurities. The salt basins of the upper Ohio and of Michigan, both distinct from and of later age than that we have been considering, show the same peculiarities. By some writers the gypsum of the Salina group, as well as that of other formations, is attributed to the action of acid waters on carbonate of lime; but the continuous sheets of gypsum contained in the Salina group, separated by thin bands of pure limestone, disprove this theory. They are evidently chemical precipitates from saline waters, alternating with the limestones, which were formed from the hard parts of organisms inhabiting the water during the intervals when it was pure enough to sustain animal life."

Pennsylvania.—There are sixteen establishments in the State engaged in making salt. Of these only four have reported for 1884, in which year they employed 51 hands and paid $26,071 in wages, the total value of their products (including, however, some other chemicals) being $121,468.

Ohio.—The production of 1883 is estimated at 350,000 barrels, worth, at 66 cents net at the works, $231,000; and in 1884 at 320,000 barrels, worth $201,600, at an average net value of 63 cents per barrel. It is possible that these estimates are understatements, as the returns are very imperfect. The reports made by the county clerks to the secretary of state placed the make for the year ending March 31, 1884, at 2,489,000 bushels (497,800 barrels), and the total value of the product at $557,810; but there is evidently an error in these figures, as the valuation would indicate an average price of $1.12 per barrel, or nearly twice as much as the actual rate, the highest average for 1883, as estimated by manufacturers, having been 70 cents, and that for 1884 only 67½ cents, while the rates given above, 66 and 63 cents spot respectively, seem to be warranted by reports received. The valuation given by the county clerks may perhaps include bromine or other by-products; but if this were the case it would hardly explain the entire discrepancy, and the county clerks' figures are therefore not adopted.

The great flood in February, in addition to the depression caused by low prices, had the effect of reducing production in 1884.

The following account of the Ohio salt industry is condensed from a recent description by Prof. Edward Orton. Salt is made in the following districts, named in the order of their production: (1) the Pomeroy or Ohio Valley district, Meigs county; (2) the Tuscarawas Valley district, Tuscarawas county; (3) the Muskingum Valley district, Muskingum county; (4) the Hocking Valley district, Athens, Morgan county; (5) the Cambridge district, Guernsey county and Noble county; (6) the Eastern Ohio district, Columbiana county. The brine is obtained from two horizons, the Logan, or Upper Waverly sandstone (frequently conglomeratic), and the Berea grit, or Lower Waverly sandstone. To the first are to be referred all the wells except those belonging to the Tuscarawas valley and the eastern Ohio fields. The strongest water found in the State is about 10° Baumé, and water of this strength is derived from both the salt horizons. The manufacture is in a more or less depressed or unsatisfactory condition throughout the State. This depression arises from the sharp competition which has prevailed in all western salt markets during the last ten or fifteen years, and especially from the competition arising from Michigan salt, which has brought the price too close to the cost of production in Ohio to make the business a sound and growing industry.

The salt wells of the Pomeroy district are the most prominent. The Pittsburgh coal seam has an excellent development at Pomeroy. It lies about 150 feet above low water in the Ohio. It has a thickness of 4½ feet, increasing in the swamps to 6 feet. A large area immediately adjoining the river originally held the seam, and mining has been carried on vigorously for a long term of years. The seam is not homogeneous, but it consists of two benches quite unequal in thickness and also in quality. The lower bench, 3 to 3½ feet thick, is of a much better character than the top bench. The latter is 12 to 15 inches in thickness and is high in ash and sulphur, and also carries a cannel streak. It was long ago found that the character of the entire seam was greatly lowered by sending out the top coal, and it finally became necessary to reject it altogether from the coal supplied to the river market. A large amount of coal, one-quarter at least of the entire seam, was therefore to be thrown into the waste, cumbering the mine and reducing the output. To use this inferior coal and also the slack and screenings produced by mining, it was decided by the proprietors of the Pomeroy field to establish salt furnaces, provided a supply of brine could be obtained. The Ohio Valley salt interest was thus distinctly based upon the low-grade coal of the upper bench of the Pittsburgh seam at this point. Drilling for salt water was begun about 1850, and a good supply was found at a depth of 1,010 feet in the pioneer well of the Pomeroy Salt Company. A smaller supply was passed at 300 feet in the Mahoning sandstone. The well head is about 60 feet below the level of the coal seam, making the main salt rock about 1,075 feet beneath the Pomeroy coal, or about 600 feet below the place of the Nelsonville coal. This shows the salt rock to be the Logan sandstone or Upper Waverly, which has already been found supplying the salt wells of both the Muskingum and the Hocking valleys. The brine is supplied in good quantity. For some time after drilling the first wells it flowed from the well heads, but it was soon found necessary to pump the brine, and the length of the lift has been gradually increased until the present time. It is now lifted about 500 feet. The well is cased to 600 feet, and the salt water rises about 100 feet in the casing. Aside from this there is no falling off in the supply. The strength of the brine is moderate, reading about 10.75° on the Baumé scale. This strength has been uniformly maintained in all of the wells, except when one or another may be temporarily invaded by fresh water from above. The brine carries but a small amount of sulphates, but it holds considerable iron, and, like other Ohio brines, is extraordinarily rich in bromides. There are now in operation in this district 15 furnaces. At one time there were 26 in operation—13 on each side of the river. The business was fairly successful from its beginning until the end of the war. After the war was ended the work of resupplying the southern States with salt, for which Ohio was most advantageously situated, brought an extraordinary but short-lived prosperity to this field, which in the end proved a real misfortune. The success of the business at this time attracted $2,000,000 of new capital, and the production was brought up to a maximum of 1,200,000 barrels annually—a larger quantity of salt than the regions naturally tributary to the Ohio valley could make use of. At about the same time the competition of Saginaw salt began to be felt, and the Ohio valley manufacture has since been carried on at a confessed disadvantage. The barrel in which the salt is packed costs not less than 30 cents, southern Ohio oak, which is the most accessible lumber supply, being discarded and replaced by elm and other white woods, mainly from northern Ohio. The price of salt on the yards falls as low as 70 cents (and lower) at times. This leaves 40 cents for manufacturing and packing 280 pounds of salt. It requires great skill in management and great economy in every expenditure to make 7 pounds of salt for one cent and save any profit. But in reality the manufacture is not conducted with the highest degree of economy. As previously stated, the upper bench of the coal mined here, together with the slack produced in mining, was the original reliance of the salt furnaces as to fuel, and most of them adhere to the old practice. A few, however, use the whole product of the mines, and it is a question whether the superior efficiency of the fuel derived from the entire seam does not fully compensate for the increased expense. For transportation Pomeroy has mainly relied upon the Ohio river, but within the last few years railroads have reached the town, and salt can be shipped by them at fair advantage when the river is not available.

In what is known as the Tuscarawas Valley salt field, three furnaces are now in operation: the Sugar Creek Salt Works, at Canal Dover; the Dover Salt Works, at Canal Dover; and the Goshen Salt Works, 3 miles above New Philadelphia. Each of them depends on a single well, and each uses the entire product. The capacity of the three is about 60,000 barrels per year, the Sugar Creek Company producing more than either of the others. This field is generally counted the most successful in Ohio at the present time. The wells are about 900 feet in depth, all of them reaching unmistakably the Berea grit, which yields gas in connection with the brine. The water now requires to be lifted 500 feet. Its strength is about 10° Baumé, sometimes gaining a little on this. The New Philadelphia well was the first to be drilled, in 1866–'67. The object sought for in drilling was oil. The other wells followed in close succession. A fourth well drilled near Dover failed to produce brine, but the supply of brine may be counted as practically unlimited. The quality of the salt produced is good. It finds its chief market in central Ohio. There is but a small proportion of sulphates in the brine. The processes used in the manufacture are a blending of the old and new. Steam is used in the evaporation in part only. Two of the companies mine their own coal, depending on the Middle Kittanning or No. 6 seam, which is very accessible. The Sugar Creek furnace makes use of slack exclusively, drawing its supply from the Pike Run and Cambridge mines.

The Scott Salt Works, 3 miles above Cambridge, on the line of the Central Ohio railway (Baltimore and Ohio), are the only important works in Guernsey county. Their production is about 4,500 barrels per year. Two or three small furnaces are situated in the Wills Creek valley that have outlived their usefulness, but that still maintain a feeble production. Two wells have been drilled at Scott's works. The main salt rock lies here 620 to 650 feet below the Cambridge coal, which shows it to be the Logan sandstone. They are begun near the level of the middle Kittanning seam, upon which they depend for fuel. They are thus seen to agree with the Scott wells as to the horizon from which the brine is derived. The brine is weak, not rising to 10.7° Baumé, but it is said to be unusually free from impurities. The percentage of sulphate of lime, of iron, and of bromides are all low. The pea coal and the slack of the large mine that is worked here furnish all the fuel for the furnaces. The salt has an excellent name in all of the markets that it reaches. The Wills Creek valley was one of the early sources of Ohio salt. All of the early wells bored here are said to have found a notable quantity of gas in the salt rock.

Quite an extensive production of salt was maintained in Columbiana county for a number of years, the manufacture being chiefly confined to the valleys of Yellow Creek and Little Beaver, but it has almost entirely disappeared under the competition that has come in from outside fields. One furnace is still in operation near New Lisbon, and several have been operated within the last few years in the Ohio valley below East Liverpool. The horizon from which the salt water is derived clearly seems to be the Berea grit. The brine is weak, not exceeding 5° or 6° Baumé.

Noble county is to be credited with a single salt furnace, now, or recently, in operation. The well is shallow, and the brine is derived from a Coal Measure sandstone, probably one of the divisions of the Mahoning sandstone. The production is insignificant.

West Virginia.—The salt industry of this State, also, is in a depressed condition, due to the recent sharp competition. The brine wells are mainly in Kanawha and Mason counties. The output is estimated by Dr. J. P. Hale to have been only about 320,000 barrels, of 280 pounds, in 1883, or 20 per cent. less than in 1882. In 1884 the yield still further declined, and probably did not exceed 310,000 barrels. The average value at the works in 1883 was about 66 cents, and in 1884 about 63 cents per barrel.

Estimated production of salt in West Virginia, 1882 *to* 1884, *inclusive.*

Years.	Barrels.	Value.
1882	400,000	$300,000
1883	320,000	211,200
1884	310,000	195,300

The earlier history of the salt manufacture of Kanawha county is shown in the following table, prepared by Dr. Hale:

Production of salt in Kanawha county, West Virginia.

Years.	Quantity.	Years.	Quantity.
1797 pounds per day	150	1846 bushels per year	3,224,786
1808 bushels per day	25	1847 do	2,690,087
1814 bushels per year	600,000	1848 do	2,876,010
1827 do	787,000	1849 do	2,951,492
1828 do	863,542	1850 do	3,142,100
1829 do	989,758	1851 do	2,862,676
1830 do	906,132	1852 do	2,741,570
1831 do	956,814	1853 do	2,729,910
1832 do	1,029,207	1854 do	2,233,863
1833 do	1,288,873	1855 do	1,498,548
1834 do	1,702,956	1856 do	1,264,049
1835 do	1,960,583	1857 do	1,266,749
1836 do	1,762,410	1858 to 1863	(*a*)
1837 do	1,680,415	1864 do	1,300,991
1838 do	1,811,076	1865 do	861,973
1839 do	1,593,217	1866 do	1,275,017
1840 do	1,419,205	1867 do	1,321,066
1841 do	1,443,645	1868 do	1,528,282
1842 do	1,919,389	1869 do	1,822,430
1843 do	2,197,887	1870 do	1,721,963
1844 do	1,874,919	1871 to 1874	(*a*)
1845 do	2,578,499	1875 do	967,465

a No records.

Virginia.—Rock salt and brines occur at Saltville, Smythe county; and brines are also met with in Washington and Lee counties. The Norfolk and Western railroad carried 1,214 tons of salt in 1882, and 11,482 tons in 1883, the source of which is not reported. Mr. Thomas Radcliffe makes the following statement as to the salt of the Holston valley, near Saltville: "A specimen of the rock salt sent by the superintendent of the salt works was brownish red in color, with a crystalline structure, and was obtained while deepening one of the salt wells. This rock salt is not mined, the brine alone being used for the manufacture of salt. The capacity of the works is at present 450,000 bushels per year, though at one time during the late war the yield was as high as 10,000 bushels per day. According to analysis the rock salt contained—

	Per cent.
Sodium chloride	93.05
Potassium chloride	Trace.
Calcium sulphate	2.40
Magnesium sulphate	.07
Ferric oxide	.83
Silica	2.81
Water	.30
	99.46

"An analysis of the marketed salt gave 98.89 per cent. sodium chloride, with a small percentage of calcium sulphate, water, and a trace of magnesium sulphate, showing it to be a high-grade salt."

North Carolina.—There are brine wells, not largely utilized, in the Triassic beds of Chatham, Orange, and Rockingham counties.

Louisiana.—The great rock salt mass of Petite Anse, or Avery's island, near New Iberia, in the southern part of the State, is practically the sole source of commercial salt in the State. Its product, however, is very great, and could be increased with a more favorable market. Mr. William Crooks, superintendent of the American Salt Company, operating the Petite Anse mine, furnishes the following statistics of its output during the past three years:

Production of the Petite Anse mine in 1882, 1883, *and* 1884.

Grades.	1882.	1883.	1884.
	Short tons.	*Short tons.*	*Short tons.*
Lump	20	405	1,485
Crushed	5,995	10,595	7,550
Coarse	16,595	22,480	15,750
Fine	2,940	3,625	6,280
Table		25	290
Total	25,550	37,130	31,355

The Petite Anse mine is about 160 miles west of New Orleans and about 180 miles east of Galveston. It was very fully described in the previous report, pages 558 to 565. It is an immense block of rock salt, estimated by Professor Hilgard to contain about 2,800,000 short tons in sight, and by the company's engineer to contain, conditionally upon certain measurements and estimates, 28,600,000 tons. The salt is heavier than made salt, the company claiming that a bushel of rock salt weighs 110 pounds. Analyses of the salt are as follows:

Analyses of Petite Anse salt.

	By Peter Collier.	By Dr. Riddle.	By Professor Goessmann.	By E. W. Hilgard.	By Joseph Jones.	By F. W. Taylor.	By Dr. Doremus.	By Gustavus Bode.
Sodium chloride	98.900	98.88	98.88	09.880	99.617	98.731	99.0972	99.252
Calcium sulphate	.838	.76	.79	.126	.318	1.192	.7293	.694
Calcium chloride	.146	.13	trace	trace		trace		.042
Magnesium chloride	.022	.23	trace			.013		.012
Magnesium sulphate					.062		.1584	
Insoluble residue	.014					.034		
Moisture at 300° F					.003			
Moisture at 220° F	.080		.33			.030	.0389	
	100.000	100.00	100.00	100.006	100.000	100.000	100.0238	100.000

The grades of Petite Anse salt are as follows: "Lump" is the rock, just as mined, in lumps of 50 to 300 pounds, and is used by stockmen; "crushed" is the salt broken by rock-crushers and screened into various grades, corresponding to Turk's island and the different sizes of solar salts; "coarse" is made finer than the last by grinding it to correspond in grain with Liverpool coarse or "ground alum," as it sometimes is called; "fine" is ground still smaller, and corresponds to Liverpool fine; "table" is ground for table use. The price at the mine in 1884 averaged: Lump, $6; crushed, $3.50; coarse, $3.75; fine, $4.75; table, $5, per ton.

The other principal salines of Louisiana were described by Professor Hilgard in the 1882 report. They consist of salt licks, brine pools, lakes, etc., in the northern part of the State. The salt from these is used to a small extent locally, but is not on the market. A little sea water has been boiled at times along the gulf coast between the mouths of the Mississippi and Atchafalaya rivers. The amount thus produced is at present insignificant.

Texas.—A number of extensive lagoons or sea marshes are met with in the neighborhood of Corpus Christi and farther west, where salt forms by natural evaporation of the water which floods them at periods of very high tides. This salt is gathered and used to some extent by ranchmen and others. There are also salt lakes of considerable extent farther inland, in Hidalgo and Cameron counties, where the salt formed naturally has a small local use; and in the northwestern part of the State, near El Paso, are similar lakes, which before the advent of railroads supplied the population on both sides of the Rio Grande. A little salt has been made at Graham, Young county, at a small block, making salt from brine with the aid of natural gas. Regarding one of the Hidalgo county salines the following description has been furnished: La Sal del Rey lake is in form an ellipse, about 1 mile in length and 5 miles in its circumference. Its depth nowhere exceeds 3 or 4 feet, and its bed consists of pure rock crystal salt. The water is a brine of unusual strength, which crystallizes with such rapidity that if a large quantity of salt is removed from the bed of the lake one day, it is said that its place will be found filled with salt of a similar quality the next. This indicates that the supply of salt is very great, while in purity it ranks very high, as shown by an analysis by Dr. Riddle, which gave 99.09 per cent. sodium chloride, 0.51 per cent. insoluble matter, and traces of magnesium sulphate.

Illinois.—The salt wells of Gallatin, Jackson, Marion, Vermillion, Saline, and Calhoun counties have produced very little salt of late years.

Indiana.—There are saline springs or borings in the sub-Carboniferous rocks in Putnam, Warren, Jackson, Clark, Floyd, Scott, Harrison, Fountain, Franklin, Dearborn, and Vigo counties. The salt production of Indiana is small, owing to the competition of the supplies from the neighboring States.

Kentucky.—Brine is obtained and evaporated from wells in the eastern coal fields and the sub-Carboniferous limestones of the western part of the State. There are also weak brines in the central counties.

Tennessee.—There are salt works in White, Anderson, and Overton counties. Brine has been found in borings for petroleum in some of the central counties.

Missouri.—There was formerly a considerable production in Saline, Sainte Genevieve, and Jefferson counties; but the industry has declined.

Kansas.—There are a large number of brine wells and some deposits of rock salt, said to be very extensive, in this State; but the output of salt is not large.

Arkansas.—Rock salt is found in Dallas and Hot Springs counties, but has not been utilized to any extent.

Nebraska.—Several springs have been found along Salt creek, Lancaster county.

Rocky Mountain region.—Salt is found in considerable quantities in various portions of the Rocky mountains, from Montana to Mexico, both in salt springs and as salt beds or deposits. In the Yellowstone valley salt springs occur frequently, but no effort has yet been made to utilize the brine in the manufacture of salt. In Wyoming, rock salt is said to occur in extensive beds in the western portion of the territory, and in Crook county, west of the Black Hills. At Jenny's Stockade, Dakota, a number of springs furnish an excellent quality of salt, and the supply of brine is abundant. These springs are owned by Captain Davey, of Galena, Black Hills, who has evaporated a considerable quantity of brine and sold the salt. He has manufactured during the latter part of 1884 about 3 tons of salt daily. This salt supplies the Black Hills towns.

In the South Park, Colorado, there are a number of salt springs. Before 1870 works were erected with a capacity of many barrels of salt daily, but for some reason they proved a failure and have not been running for years. It is not possible to ascertain how much salt has been produced and marketed.

In New Mexico, on the great plateau of the Rocky mountains, southwest of Cañon Blanco summits, are the Salinas, which furnish a large quantity of good salt. The greater portion of New Mexico is supplied from here, it being freighted to Santa Fé, Las Vegas, to the towns along the Rio Grande, and even to Chihuahua. The only cost is that of transportation. It occurs in quantity in many places in New Mexico, often mixed with alkali, and also pure in lakes. The evaporation in the salt lakes annually makes a deposit of salt several inches in thickness, coarse, strong, and of the best quality. It has often been taken to the city of Chihuahua for sale, as the salt of that State is inferior, being mixed with alkali. The principal lakes are in the valley between the Organ and the Sacramento mountains, one lake on the Texas line, and the best one 60 miles northward, and another large and excellent one about 60 miles south of Santa Fé, near the town of Manzano, whence many wagon loads are regularly carried to Santa Fé and other distant points, the article forming quite a commodity of interior commerce. These salt lakes have been used as public property.

Utah.—Rock salt deposits in great masses are found in San Pete county; this rock salt is usually tinged with red or brown clays, but occasional lumps are as clear as crystal. Salt also occurs in large quantity in Juab, Millard, and Sevier counties, and small amounts have been taken from a number of localities in the Territory. At present, however, almost the whole production comes from the waters of Great Salt lake. The method of obtaining the salt is to overflow marshes or basins in the spring, shutting the water in by dirt walls. Solar evaporation causes a deposit of salt to be formed. The expense of gathering it is very light, the cost being mainly in handling it to the railway, from 3 to 10 miles from the salt flats. The largest shippers are Lyman & Wallace, but other firms and persons are engaged in the business. The quality of the salt is in proportion to the care bestowed on its manufacture. Good table salt may be selected from the evaporated salt, but there is usually too much dirt, consisting of dust blown in from the adjoining lands. The chief demand is for use in silver mills in Utah, Idaho, Montana, Nevada, and Colorado. The lake supply is enormous, as the surface is so great, ranging between 1,750 and 2,100 square miles in late years; the mean depth varying from 13 to 18 feet, and probably being about 16 feet at present; while the salinity has ranged between 14 and 21 per cent., being now about 17 per cent. The production during the past six years, as estimated by Mr. J. M. Goodwin, of the Salt Lake City *Tribune*, is given below. In the spring of 1884 a large quantity of salt was lost by the unexpected overflow of some land on which it had been piled.

Salt production of Utah since 1879.

Years.	Quantity.	Value.
	Short tons.	
1879	12,000	$60,000
1880	12,000	60,000
1881	14,000	70,000
1882	13,000	65,000
1883	15,000	60,000
1884	16,000	80,000

The average price, loaded on cars, was $4 per short ton in 1883 and $5 in 1884. In 1884 about 200 tons (included in the total given above) were made into table salt, by boiling and skimming the lake water.

The following analyses of the water of Salt lake have been compiled by Mr. G. K. Gilbert, and will also appear in his monograph on "Lake Bonneville," shortly to be published. No. 1 is of a sample taken in 1850 and analyzed by L. D. Gale; No. 2 is of a sample taken in the summer of 1869, analyzed by O. D. Allen; No. 3 is of a sample taken in August, 1873, analyzed by H. Bassett. There are some slight inconsistencies in the analyses, but they are given as originally reported.

Analysis No. 1 was taken at an unusually low stage of water, and showed 22.28 per cent. of solid matter.

Analyses of the water of Great Salt lake.

	Parts in 1,000 of water.			Per cent. of total solids.		
	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
Chlorine	124.5	84.00	73.6	55.8	56.0	54.9
Sulphuric acid, (SO_4)	12.4	9.87	8.8	5.6	6.6	6.6
Sodium	85.3	49.65	38.3	38.3	33.1	28.5
Potassium	....	2.40	9.9	....	1.6	7.4
Calcium	trace.	.25	.6	....	.2	.4
Magnesium	.6	3.77	3.0	.3	2.5	2.2
Boric acid	....	trace.	....	....	....	....
Phosphoric acid	....	trace.	....	....	....	....
	222.8	149.94	134.2	100.0	100.0	100.0

Theoretically combining acids and bases, the results are as follows:

	Parts in 1,000 of water.			Per cent. of total solids.		
	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
Sodium chloride	202.0	118.63	91.8	90.7	79.1	67.7
Potassium chloride	....	....	18.9	....	....	14.0
Magnesium chloride	2.5	14.91	11.9	1.1	9.9	8.8
Sodium sulphate	18.3	9.32	10.9	8.2	6.2	8.0
Potassium sulphate	....	5.36	....	....	3.6	....
Calcium sulphate	....	.86	2.0	....	.6	1.5
Clorine (excess)	....	.86	....	....	.6	....
	222.8	149.94	135.5	100.0	100.0	100.0

California.—For information in regard to the occurrence of salt in the Pacific division, including production, consumption, exports, etc., the reader is referred to the first volume of these reports, where the subject is treated with considerable fullness. During the past two years salt has been produced in that section of country from the same sources and at about the same rate as before, the output in California having been in 1884 somewhat less than usual, owing to the shortness of the working season. The number of tons of salt produced in California during the past five years has been as follows, the quantity made and consumed in the State over and above receipts reported at San Francisco being estimated:

Years.	Short tons.
1880	14,000
1881	17,000
1882	19,000
1883	30,000
1884	25,000

More than nine-tenths of this salt was made by the various companies operating on the eastern shores of San Francisco bay, in Alameda county, where extensive vats or reservoirs for solar evaporation have been constructed. The importations of salt at the port of San Francisco during the past five years have been as follows:

Imports of salt at San Francisco.

	1880.	1881.	1882.	1883.	1884.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
English	13, 828, 066	7, 745, 468	12, 841, 212	8, 543, 878	8, 500, 000
Carmen island	3, 542, 000	2, 730, 000	761, 600	21, 046	15, 000
Peru	----------	----------	1, 200, 000	----------	----------
Total	17, 370, 066	10, 475, 468	14, 802, 812	8, 564, 924	8, 515, 000

From the foregoing it will be seen that as the local product has been increased importations have fallen off, and that the latter may ultimately cease altogether, as the California-made salt is every year being slightly reduced in price and at the same time improved in quality. Formerly it was considered unfit for meat packing, dairy, or table use; now it is largely employed for all purposes, being liked nearly as well as the Liverpool. The rate at which the manufacture of salt in California has increased in value and importance is indicated by the following table:

Progress of the salt industry of California.

	1860.	1870.	1880.
Bushels made	44, 000	174, 855	884, 443
Value	$7, 100	$48, 150	$121, 250
Wages paid	5, 400	13, 400	49, 120

The following statement shows the condition of the industry in California in 1883:

Number of companies	27
Companies making salt by solar evaporation of sea water	24
Companies working natural salt beds	22
Evaporating salt water from wells by graduation	1
Number of men employed	285
Capital invested	$475, 000
Wages paid	$75, 000
Value of annual product	$300, 000
Number of reservoirs or vats	200
Aggregate area in square feet	15, 000, 000
Number of tons of salt made from sea water	27, 000
Number of tons of salt made from other sources	3, 000

The spring rains of California having been protracted in 1884 some four or five weeks beyond the usual period, shortened the working season of the Alameda county companies to that extent, thereby reducing the output of bay salt for the year by about 5,000 tons.

The foreign salt now arriving at San Francisco comes almost exclusively from Liverpool, importations from Carmen island, Lower California, and Peru having fallen off. Only in 1882 was any salt imported from the latter country, shipments that year having been due to peculiar circumstances not likely to recur. Owing to the accumulation of ample stocks the price of salt has been low in San Francisco for the past two years, Liverpool salt having sold for a part of the time below $12 per ton, barely enough to cover freight and charges. Owing to the shortage of the home product in 1884, prices improved towards the end of that year, ruling in the early part of 1885 at $15 to $18 per ton for Liverpool; California rock salt, $8 to $10; half ground, $10 to $12; Carmen island, $14 to $18. The yearly exports of salt from San Francisco amounted to between 500 and 600 tons, sent to Oregon and Washington Territory.

The new sources of salt production in California consist of the extensive saline opened in 1884 near Dos Palmos station, on the Southern Pacific railroad, San Diego county, and a well near the town of Yreka, Siskiyou county, which, having been bored to a depth of 675 feet, has since discharged a strong brine at the rate of 10,000 gallons per hour. Salt to the amount of several hundred tons has been produced here by the method of graduation, and there being a local demand for all that can be made, the business has proved profitable. Salt can not be carried to this portion of the State from San Francisco, the only other supplying point, at less than $40 per ton, which enables the local manufacturers to charge high prices for their product.

The Liverpool Salt Company, owners of the Dos Palmos bed, took out last year 1,500 tons of salt, which was marketed in the southern part of the State and in the adjacent Territory of Arizona, which localities will most likely continue to obtain their supplies from that source. This company, having made arrangements for working its deposit on a large scale, will probably produce hereafter several thousand tons of salt annually. A stratum of nearly pure salt several inches in thickness occurs at this point, covering many hundred acres. Under this is a lake of brine carrying from 25 to 30 per cent. chloride of sodium and said to be free from iron and sulphur. This surface incrustation, having been broken up and suffered to fall into the brine beneath, is there slightly agitated in order to wash off the small quantity of mud and sand it contains. This done, it is ready for market, being quite pure and sufficiently clean for ordinary uses. The company has constructed large vats for holding the brine, which is evaporated by solar heat, the climate being extremely favorable for that system. But little rain ever falls in this part of California, and the mean temperature for seven months in the year is not much below 100° Fah. Works will be put up either on the ground or elsewhere for making table and the other finer grades of salt. The Southern Pacific Railroad Company, with a view to facilitating the shipment of salt, has laid down a mile and a half of track connecting the salt works with their main line at the Dos Palmos station.

Nevada.—The Eagle Salt Works, Churchill county, Nevada, produced

1,200 short tons of salt in 1883 and 1,000 tons in 1884. The latter season was a bad one, losses being caused by rains. The average value at the works was $5 per ton during the two years. The works made 200 tons of table salt in each year (included in the total stated above), the remainder being mill salt used in silver amalgamation, "rock," "stock," and "Liverpool fine." Mr. C. M. Willey, superintendent of the Eagle works, estimates the total output of salt in Nevada at 3,000 short tons in 1883 and 2,500 tons in 1884. Were there a market for the product the amount made could be increased indefinitely. The salines of the Rio Virgen and the others of Churchill, Esmeralda, and Lander counties were fully described in the previous report.

The brines from the Buffalo salt wells and from the Eagle works contain, according to analyses by Mr. F. W. Taylor:

Analyses of Nevada brines.

	Buffalo.	**Eagle.**
	Per cent.	*Per cent.*
Sodium chloride	14.8383	25.3793
Sodium sulphate	.5306	....
Potassium chloride	....	.0023
Potassium sulphate	.3111	....
Calcium chloride	....	.3578
Calcium sulphate	.1467	.2897
Magnesium chloride	....	.3787
Magnesium sulphate	.8833	....
Silica in solution	trace.	....
Insoluble silica	....	.0028
Iron and alumina (insoluble)	....	.0004
Water	83.2900	73.5890
	100.0000	100.0000
Specific gravity	1.1330	1.2115

Idaho.—The Oneida company continues to make salt in Salt Spring valley, Idaho, the works being on the line of the old emigrant road leading from South Pass to Oregon. The production here is about 800,000 pounds of salt yearly, which finds a market in Idaho, Montana, and adjacent parts of Utah.

Arizona.—Within the past few years an extensive deposit of salt has been found at a point between Dos Cabesas and the Dragoon mountains, but as yet it has not been utilized to any great extent. It is reported as occurring at the headwaters of Salt river and in Tonto basin, Gila county. Along the Verde river it is found in association with gypsum, sulphate of soda, and sulphate of magnesia. A little of this salt has been used for cattle. The production is still very small.

Foreign statistics.—The production of salt in Great Britain in 1882 was 2,135,499 long tons, valued at £615,316; and in 1883 it was 2,325,720 long tons, worth £669,760. Of the output in 1883 there were 233,170 tons of rock salt, 1,989,384 tons of "white" salt, and of salt contained in brine used in the ammonia process of soda manufacture 110,400 tons, besides a small quantity of "white" salt made from rock salt, not included in the total. The Cheshire district is the largest producer, but

Durham is growing in importance. The production of France in 1882 was 380,000 metric tons. Prussia produced 208,240 metric tons of rock salt in 1883, while the whole German empire (and Luxembourg) produced 456,958 metric tons of brine salt and 311,907 tons of rock salt in 1881, and 459,499 tons of brine salt and 322,422 tons of rock salt in 1882. In Austria-Hungary the salt trade is a government monopoly, and is said to yield a profit of about $10,000,000 annually in Austria and $6,250,000 in Hungary, or $16,250,000 in all.

Among other foreign sources may be mentioned the rock salt of the Pyrenees and the rock salt and brines of other parts of Spain; the rock salt of Italy and the rock salt and brines of Switzerland; the heavy deposits of Galicia; the salt lakes of Asiatic Russia; the brines of western China on the borders of Thibet; the very abundant lakes and dry salines of Persia; the rock salt of the Punjaub, India; the salines of Morocco, Barbary, Algiers, and south Africa; and the numerous deposits of South America. Sea salt is made in very many parts of the world.

Analyses of different salts.—The following table is taken from the "American Cyclopedia":

Analyses of salt from different localities.

Localities.	Chloride of sodium.	Chloride of potassium.	Chloride of calcium.	Chloride of magnesium.	Sulphate of lime.	Sulphates of magnesia and soda.	Alumina and iron.	Residue.	Water.	Authorities.
Rock salt.										
Petite Anse, Louisiana	98.88	......	trace	trace	0.79	......	......	......	0.33	Goessmann.
Wieliczka, Austria	100.00	......	......	trace	......	......	......	......	......	Bischof.
Berchtesgaden	99.928	......	......	0.07	......	......	......	......	......	Do.
Hall, Tyrol	99.43	......	0.25	0.12	0.20	......	......	......	......	Do.
Hallstadt, Austria	98.14	trace	......	......	1.86	......	......	......	......	Do.
Stassfurt, Prussia	94.57	......	......	0.97	0.89	......	1.12	2.23	0.22	Heine.
Vic, German Lorraine	99.30	......	......	......	0.50	......	0.20	......	......	Berthier.
Jeb el-Melah, Algeria	97.00	......	......	......	3.00	......	......	......	......	Fournet.
Ouled Kebbah, Algeria	98.53	......	0.93	0.54	......	......	......	......		Do.
Carrickfergus, Ireland	96.28	......	......	......	3.50	0.08	......	......	0.14	G. H. Cook.
Santo Domingo	98.33	......	......	0.04	1.48	......	......	0.01	0.07	Goessmann.
Salt from springs and lakes.										
Onondaga, New York	97.41	......	0.15	0.18	1.26	......	......	......	1.00	G. H. Cook.
Pittsburgh, Pennsylvania	96.70	......	0.53	0.07	......	......	......	......	2.70	Do.
Kanawha, West Virginia	91.31	......	1.26	0.43	......	......	......	......	7.00	Do.
Saginaw, Michigan	92.97	......	1.09	0.50	0.33	......	......	0.01	5.10	Do.
Hocking Valley, Ohio	95.07	......	0.61	0.04	0.10	......	......	......	3.40	Goessmann.
Pomeroy, Ohio	96.42	......	0.53	0.18	......	......	0.05	0.16	2.66	E. S. Wayne.
Cheshire, England	96.36	......	0.01	0.02	1.17	......	......	......	2.44	G. H. Cook.
Dieuze, German Lorraine	97.59	......	......	......	1.02	0.89	......	......	0.50	Do.
Droitwich, England	96.93	......	......	0.02	3.05	......	......	......	......	Do.
Goderich, Ontario	97.03	......	0.01	0.03	1.43	......	......	......	1.50	Goessmann.

Imports and exports.—The imports of salt into the United States since 1867 and the exports from this country since 1790 are shown in the following tables. While the quantities are doubtless given correctly, there are apparent discrepancies in the values as reported:

Salt imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Cake, over 30 per cent. of potash.		In bags, barrels, and other packages.		In bulk.		For the purpose of curing fish.		Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*		
1867	....	....	254, 470, 862	$696, 570	229, 304, 323	$336, 302	....	....	$1, 032, 872
1868	....	....	308, 446, 080	915, 546	219, 975, 096	365, 458	....	....	1, 281, 004
1869	....	$1, 752	297, 382, 750	895, 272	256, 765, 240	351, 168	....	....	1, 248, 192
1870	....	9, 698	288, 479, 287	797, 194	349, 776, 433	507, 874	68, 597, 023	$87, 048	1, 401, 814
1871	....	2, 436	283, 993, 799	800, 454	274, 730, 573	355, 318	64, 671, 139	66, 008	1, 224, 216
1872	....	....	258, 232, 807	788, 893	257, 637, 230	312, 569	57, 830, 929	60, 155	1, 161, 617
1873	....	....	339, 494, 117	1, 254, 818	388, 012, 142	525, 585	86, 756, 628	86, 193	1, 866, 596
1874	....	....	358, 375, 496	1, 452, 161	427, 294, 209	649, 838	105, 613, 913	126, 896	2, 228, 895
1875	....	1, 867	318, 673, 091	1, 200, 541	401, 270, 315	549, 111	110, 249, 440	119, 607	1, 871, 126
1876	....	....	331, 266, 140	1, 153, 480	379, 478, 218	462, 106	118, 760, 638	126, 276	1, 741, 862
1877	....	....	359, 005, 742	1, 059, 941	444, 044, 370	532, 831	132, 433, 972	140, 787	1, 733, 559
1878	....	....	352, 109, 963	1, 062, 995	414, 813, 516	483, 909	100, 794, 611	96, 898	1, 643, 802
1879	....	2, 480	375, 286, 472	1, 150, 018	434, 760, 132	532, 706	94, 060, 114	95, 841	1, 781, 045
1880	....	21, 667	400, 970, 531	1, 180, 082	449, 743, 872	548, 425	109, 024, 446	119, 667	1, 869, 841
1881	1, 397, 579	8, 187	412, 442, 291	1. 242, 543	5[illegible]9, 361, 042	658, 068	133, 395, 065	144, 347	2, 053, 145
1882	8, 954, 834	55, 622	329, 969, 300	1, 086, 932	399, 100, 228	474, 200	134, 777, 569	147, 058	1, 763, 812
1883	7, 863, 756	43, 363	312, 911, 360	1, 035, 946	412, 938, 686	451, 001	142, 065, 557	154, 671	1, 684, 981
1884	*a*8, 416, 147	40, 646	340, 759, 010	1, 093, 628	441, 613, 517	433, 827	126, 605, 276	122, 463	1, 690, 564

a Classed as "salt cake;" amount of potash not specified.

Salt, of domestic production, exported from the United States.

Fiscal years ending September 30 until 1842, and June 30 since—	Quantity.	Value.	Fiscal years ending September 30 until 1842, and June 30 since—	Quantity.	Value.
	Bushels.			*Bushels.*	
1790	31, 935	$8, 236	1857	576, 151	$190, 699
1791	4, 208	1, 052	1858	533, 100	162, 650
1830	47, 488	22, 978	1859	717, 257	212, 710
1831	45, 847	26, 848	1860	475, 445	129, 717
1832	45. 072	27, 914	1861	537, 401	144, 046
1833	25, 069	18, 211	1862	397, 506	228, 109
1834	89, 064	54, 007	1863	584, 901	277, 838
1835	126, 230	46, 483	1864	635, 519	296, 088
1836	49, 917	31, 943	1865	589, 537	358, 109
1837	99, 133	58, 472	1866	670, 644	300, 980
1838	114, 155	67, 707	1867	605, 825	304, 030
1839	264, 337	64, 272	1868	624, 970	289, 936
1840	92, 145	42, 246	1869	442, 947	190, 076
1841	215, 084	62, 765	1870	298, 142	119, 582
1842	110, 400	39, 064	1871	120, 156	47, 115
1843 (nine months)	40, 678	10, 262	1872	42, 603	19, 978
1844	157, 529	47, 755	1873	73, 323	43, 777
1845	131, 500	45, 151	1874	31, 657	14, 701
1846	117, 627	30, 520	1875	47, 094	16, 273
1847	202, 244	42, 333	1876	51, 014	18, [illegible]78
1848	219, 145	73, 274	1877	65, 771	20, 133
1849	312, 063	82, 972	1878	72, 427	24, 968
1850	319, 175	75, 103	1879	43, 710	13, 612
1851	344, 061	61, 424	1880	22, 179	6, 613
1852	1, 467, 676	89, 316	1881	45, 455	14, 752
1853	515, 857	119, 729	1882	42, 085	18, 265
1854	548, 185	159, 026	1883	54, 147	17, 321
1855	536, 073	156, 879	1884	70, 014	26, 007
1856	698, 458	311, 495			

BROMINE.

BY DAVID T. DAY.

Occurrence.—Bromine is found in small quantities, but so widely distributed as to justify the general statement that where compounds of chlorine are found corresponding bromine compounds also occur. The proportion of bromine to chlorine varies within wide limits, reaching a maximum in such waters as those of the Dead sea and a minimum in such salt deposits as those of Louisiana. From the discovery of bromine in 1826 until the opening of the Stassfurt salt mines in Germany the production of this element was insignificant, it being obtained from the mother liquors of certain salt springs, which, like that at Kissengen, contain notable traces of bromides. The production of bromine in the United States was begun in 1849 by Dr. David Alter in the salt works at Freeport, Pennsylvania, but on a very small scale. In the year 1865, according to Mylius, attention was called by A. Frank to the presence of larger quantities of bromides in the Stassfurt carnallite, and introduced the manufacture of bromine on a large scale as a secondary branch, intended to divide the cost of producing potassium salts from the Stassfurt mines, and thus aid in the competition with kelp. He also hoped that the bromine so produced would replace iodine in the manufacture of aniline dyes. The impetus thus given to the bromine industry awakened competition in West Virginia. The manufacture was actively pressed, and such quantities were sent to the European markets as to affect the Stassfurt production disastrously. From a nominal value of $8 to $16 per pound in 1865 the price of bromine fell rapidly, as it became evident that there was no adequate demand for the supply. The manufacture of bromine has been extended to the Pomeroy and Tuscarawas districts in Ohio. Bromine has never been manufactured in the Syracuse region, as the salt brines of that district contain only slight traces of bromides. As far as can be ascertained little or no bromine is manufactured in Michigan.

Production.—Nearly all the salt manufacturers in West Virginia work over the mother liquor from salt for bromine. In Ohio this "bittern" is collected from various salt works by the United States Chemical Company of Middleport, who pay a royalty to the salt works of 2 cents for each barrel of salt produced. About two-thirds of the Ohio product is produced by this establishment. As nearly as can be ascertained the total production of bromine in 1883 was 301,100 pounds, of which

194,450 pounds came from Ohio and 106,650 pounds from West Virginia. In 1884 the product was slightly less, namely 281,100 pounds, the Ohio and West Virginia proportion remaining the same. In the Tuscarawas valley, Ohio, the brines contain a larger proportion of bromine than in any other region in the United States, one pound of bromine being obtained for each barrel of salt. The Pomeroy and West Virginia works yield 1 pound of bromine to 3 barrels of salt (840 pounds).

Method of manufacture.—The process of manufacture is generally the simplest known, namely, treatment of the concentrated bittern with sulphuric acid to liberate hydrobromic acid, and manganese dioxide to oxidize the hydrobromic acid to water and free bromine; this takes place in stone vessels similar to those used in the preparation of chlorine. By heating, the bromine is distilled and collected in glass vessels. The use of potassium chlorate instead of manganese dioxide has been attempted, but has not met with marked success.

Utilization.—The consumption of bromine depends upon its use in medicine, photography, and in analytical and experimental chemistry. The hope of using its carbon compounds as substitutes for those of iodine in the industry of coal tar dyes has not yet been realized. However, Hofmann(*a*) has removed one of the obstacles to this end, that is, the greater volatility of the bromine compounds, by proposing to use amyl bromide, boiling at 120° C., together with methyl alcohol (wood spirits) or ethyl (ordinary) alcohol with the bases to which it was necessary to add methyl or ethyl. By this means methyl or ethyl bromide was formed, together with amyl alcohol; but the indifferent action of the bromides compared to the iodides, the inferior luster of the color produced, and the difficulty of recovering the more volatile bromine, have defeated the use of bromine in this field. The hope has, however, not been given up that by extended efforts bromine may yet obtain the expected importance in the color industry, since there are still some English and German manufacturers who use a mixture of ethyl and methyl bromides instead of methyl iodide. During the late civil war, and also in the Franco-Prussian war, bromine water was introduced as a disinfectant, but although possessing certain advantages over chlorine in the ease with which it may be manipulated, its use was limited. With the amounts which can be produced it is hardly possible that bromine will escape application in this field. The bleaching action of bromine is also sufficient to justify the prediction that extended use will eventually be made of it in this direction.

Price.—Since at present bromine is not used in any large industry, it is not surprising that its price should sink in proportion as the supply increases, and it has now reached a point where sales are slow at any price. By 1873 the price had fallen to 50 cents per pound. Since then the following rates have controlled the sales of wholesale quantities.

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a "Entwickelung der chem. Industrie," page 128.

These, as well as the figures for allied substances, have been kindly arranged by Messrs. Powers & Weightman, of Philadelphia:

Price of bromine per pound.

Years.	Range of prices.
1874	45, 50, 40, 37½, 35, 33, 30 cents.
1875	33 cents.
1876	33, 40, 45 cents.
1877	35 cents.
1878	30, 28, , 33, 30, 26½ cents.
1879	26½, 26, 25 cents.
1880	30, 28, 29 cents.
1881	28, 27, 26, 25, 30 cents.
1882	25, 26 cents.
1883	26, 25, 24, 22 cents.
1884	20, 28 cents.

The difficulty of selling bromine is increased by the fact that masters of vessels are unwilling to receive it as cargo, owing to the difficulty of preventing serious damages by leakage. It is therefore usually made into potassium or sodium bromide before shipment. The medicinal use of these salts, and their use as the starting point for other bromides, gives them more importance than bromine itself. The price of potassium bromide has fallen steadily, though slowly, from $1.10 per pound in 1873, to 35 cents in pound bottles (27 cents in bulk) in November, 1884.

IODINE.

By David T. Day.

Domestic occurrences.—Traces of iodides have been found, together with chlorides and bromides, in the various salt wells, particularly those of the West Virginia and Ohio district. At Saratoga, New York, traces have been detected, but although the percentage of iodine in profitable sources is extremely small, the occurrences in the United States will, in all probability, remain entirely insignificant. Although iodine is not produced in the United States, its important influence upon the bromine industry, in which the United States holds first rank, makes a consideration of the peculiar features of the iodine industry advisable.

Sources and mode of manufacture.—Sea water and the South American nitrate deposits have served as the only sources of iodine. The minute trace of iodine in the former is concentrated by many varieties of algæ, so that these plants when perfectly dry contain from 0.0297 to 0.4535 per cent. of their weight in iodine, in the form of iodides of the alkali metals (Stanford). Before the discovery of iodine by Courtois, in 1811, these algæ were collected on the shores of Ireland, Scotland, and Normandy, and their ashes ("kelp," "varec") furnished a considerable part of the soda and potash of that time. According to the report of Mr. E. C. Stanford (*a*) the production of kelp, that is, the ashes of several varities of seaweed, amounted to 20,000 tons from the western islands alone at the beginning of this century, and sold for £20 to £22 per ton. The importation of barilla then began, and this, together with the establishment of the Leblanc soda process, reduced the price of kelp to £10 per ton. Among the manufacturers of sodium salts from kelp was Courtois, in Paris. His discovery of iodine in the kelp was made at a time when theoretical discussions as to the elementary character of chlorine subjected the properties of that substance to careful study, and the analogous character of iodine led in an unusally short time to a general knowledge of this element and its possible uses. It was extracted from kelp during the preparation of soda; but small quantities fully satisfied the demand, so that its source was no more valuable than before iodine was discovered. In fact the price of kelp sank gradually to £2 per ton in 1831. Between 1841 and 1844, however, iodine was applied to the manufacture of aniline dyes. In 1845 the production of iodine began on a commercial scale, and kelp was again in demand.

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[a] *Chemical News,* Vol. 35, page 172, 1877.

The imports to the Clyde increased from 2,565 tons in 1841 to 6,000 tons in 1845. In the latter year there were four small works engaged in the manufacture of iodine; in 1846 this number increased to twenty. The kelp required was not the same; formerly that yielding most soda was needed, but this was poorest in iodides, which now became the important constituents. Moreover, it was found that kelp richest in iodine was also richest in potassium, which also was valuable; potassium chloride being worth £25 per ton. The following table gives the imports of kelp into the Clyde for thirty-five years, and also the price of iodine from the time of its industrial application up to the present. The earlier figures have been compiled by Mr. Stanford, of Glasgow, and the later prices of iodine have been furnished through the kindness of Messrs. Powers & Weightman, of Philadelphia.

Kelp imports into the Clyde, and price of iodine.

Years ending June 30—	Kelp imports.	Price of iodine.	Years ending June 30—	Kelp imports.	Price of iodine.
	Long tons.	*Per pound.*		*Long tons.*	*Per pound.*
1841	2,565	$1.20	1865	13,741	$1.84
1842	1,887	1.12	1866	8,858	2.40
1843	1,965	1.44	1867	8,174	2.88
1844	3,263	2.88	1868	8,116	3.04
1845	6,086	7.46	1869	8,978	3.12
1846	3,627	5.34	1870	9,257	3.04
1847	4,000	2.64	1871	9,384	3.44
1848	4,400	2.64	1872	10,049	8.16
1849	4,731	2.64	1873	9,449	5.12
1850	11,421	2.56	1874	10,923	*a*3.52
1851	7,320	2.08			*b*2.94
1852	5,418	3.64	1875	8,643	*a*2 44
1853	6,491	3.72			*b*2.25
1854	4,679	2.88	1876		*a*1.92
1855	5,826	3.20			*b*1.87
1856	6,349	3.28	1877		*c*3.28
1857	8,641	2.96	1878		*c*4.00
1858	8,123	2.52	1879		*c*4.48
1859	8,190	2.32	1880		*d*1.92
1860	7,754	2.04	1881		*d*2.00
1861	9,722	1.68	1882		*d*1.60
1862	9,414	1.36	1883		*d*1.28
1863	14,018	1.20	1884		*d*1.20
1864	11,349	2.00			*e*2.88

a Scotch. *b* Peruvian. *c* Combination. *d* Combination broken. *e* Recombination.

The extraordinary fluctuations in the price of iodine serve to indicate the complicated conditions of oversupply, extended production, combination of manufacturers, and open competition, to which an industry is occasionally subjected. During the early years of the manufacture the extended use of iodine, principally in the production of aniline dyes, caused sudden fluctuations in its price, while the price of the raw material remained practically unchanged. This involved many manufacturers in heavy losses, the profits under high prices usually falling to speculators, while the manufacturer was left to sustain the industry when prices were low. For this reason the number of manufacturers in Glasgow was reduced during 1873–1877 to about three, producing in all from 50 to 60 tons of iodine from about 10,000 tons of kelp. The production in France at this time was somewhat less, amounting to 40 tons, derived from 16,000 tons of inferior "varec" or kelp.

As early as 1865 the presence of sodium iodate was noticed in the South American caliche (native sodium nitrate). The effort was made by Thiercelin to extract the iodine from the mother liquors from sodium nitrate by precipitating the iodine by means of acid sodium sulphite, or, better, sodium nitrite, prepared by fusing the domestic sodium nitrate with one-fifth its weight of charcoal. But the difficulty of drying the iodine thus obtained by spreading on porous plates, and the fact that frequently the greater part of the iodine existed as sodium iodide and escaped precipitation, prevented active competition with European iodine until Langbein's method was introduced in the province of Tarapaca, then belonging to Peru, but at present held by Chili. By this method the mother liquors were treated with an excess of sodium sulphite or acid sodium sulphite, converting the iodate into hydriodic acid, from which cuprous iodide was precipitated by copper sulphate and sodium sulphite. In 1874 South American iodine was offered upon the London market for 10½ to 11 pence per ounce, against 13 pence for Scotch iodine. The result was an active competition, soon resolving into commercial warfare, which has exerted great influence upon the industry. All through 1874 Peruvian iodine was offered at prices about 20 per cent. below the Scotch product. At the beginning of 1875 both varieties sold for two-thirds the price of 1873, and the Peruvian iodine still led the way to lower prices, until at the close of 1876 the price had fallen to 5¾ pence per ounce, and both sides were ready to compromise or else give up the manufacture, which now yielded little profit to either. In order to keep up the competition the European method of producing iodine had undergone a revolution. Formerly the custom was to allow seaweed to collect during the winter months. It lay exposed upon the coasts until sometimes 90 per cent. of the iodine had been washed away from the partially decomposed weed, before it was burned and shipped to Glasgow. Further, the weed was burned in long kilns made of loose stone walls and turf; the burning seaweed here attained a very high temperature. This part of the work was done by women and children; the men then raked the ash with iron "clats" until it formed a molten slag. "During this laborious process," says Stanford, "more than 50 per cent. of the iodine is often wasted, and a large amount of potash; indeed, so intense is the heat that sufficient soda is volatilized to give an intense monochromatic flame. The high temperature also enables the carbon to deoxidize the alkaline sulphates to sulphides and other sulphur compounds; these become concentrated in the mother liquor, and entail a large expenditure of oil of vitriol, and give rise to great nuisance in the lixiviation." The first improvement, proposed in 1862, was to subject the kelp to destructive distillation in closed vessels, by which ammonia, acetic acid, naphtha, a considerable amount of illuminating gas, and finally a variety of charcoal better than others for decolorizing, etc., were obtained. From this charcoal twice as much iodine was obtained as from the kelp. This radical improvement was only used on the islands of Tyree and North Uist until the competition with Peru. The next improvement, proposed by Pellieux and Mazé-Launay, consists in drying the fresh seaweed for four or five days, then allowing it to ferment until decomposition begins. The object of the fermentation is to bring the seaweed into a condition in which no iodine will be lost in burning. The sulphur compounds in the algæ are converted into alkaline sulphides; these decompose the organic iodine compounds into alkaline iodides, which are not so easily volatilized. The water formed during the fermentation is carefully saved on account of its containing considerable iodine. The results of this process are very satisfactory. The lixiviation of iodine from the kelp is double. First, chlorides and iodides are extracted by cold water, then potassium sulphate by hot water. From the solution containing the iodides, iodine is precipitated by potassium chlorate, which separates it from small quantities of bromides. Before the end of the competition with Peru, it is said that vessels were sent out to collect seaweed for this purpose at times when the coast was bare. In March, 1877, a combination was effected between the European and South American producers, and the price set at 10½ pence per ounce. This combination was of especial value to the South American producers. It enabled them to erect new works and gave an impetus to the trade which continued even after the combination was broken in 1880. The price then fell to less than half, and with continued competition had reached by November, 1884, 3¾ pence per ounce, the same price which ruled in 1841, before iodine entered into chemical manufactures. It was predicted in November that a combination would be formed and the price then go to 9 pence per ounce. The prediction was fulfilled.

The yield from South American deposits has been estimated as follows:

Years.	Pounds.
1873	30,000
1874	100,000
1875	[a]100,000
1876	110,000
1877	200,000
1878	280,000
1879	350,000
1880	380,000
1881	200,000
1882	[b]80,000 [c]32,000
1883	[b]124,544 [c]30,000

[a] From 131 manufactories. [b] Chili. [c] Peru.

The processes have been markedly improved both in the methods and arrangement of the plant. The plant at Peruana, province of Tarapaca (formerly in Peru), erected in 1881, cost $20,000, and yields

3,200 pounds of iodine each month. The sodium nitrate at this place contains sodium iodate, which according to the *Génie Civil*, 1884, may in extreme cases amount to 50 per cent. The average mother liquor contains:

	Per cent.
Sodium nitrate	28
Sodium chloride	11
Sodium sulphate	3
Magnesium sulphate	3
Sodium iodate	22
Water	33
	100

As the iodine is present largely as sodium iodate, it is precipitated by the old method of sodium acid sulphite. Very new and economical methods are used for preparing this substance, in regard to which full plans are given in Dingler's *Polytechnische Journal*, Vol. 255, page 299. In Chili much of the iodine occurs as sodium iodide, and is exported as cuprous iodide; 117,330 pounds of this substance were exported in 1883.

Imports.—The following table shows the imports of iodine into the United States from 1867 to 1884 inclusive. The principal use of iodine in this country is for making alcoholic tincture and iodine salts, principally potassium iodide.

Iodine imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Crude.		Resublimed.		Iodine salts.	Total.
	Quantity.	Value.	Quantity.	Value.		
	Pounds.		*Pounds.*			
1867	12, 347	$28, 013	3, 199	$6, 764		$34, 777
1868	18, 994	55, 869	5, 527	16, 178		72, 047
1869	17, 241	50, 625	5, 882	18, 356	$3, 589	72, 570
1870	27, 825	70, 777	2, 233	6, 251		77, 028
1871	74, 320	212, 195	956	3, 499		215, 694
1872	81, 437	292, 998	258	2, 166	41	295, 205
1873	48, 991	206, 783	10	87		206, 870
1874	23, 861	89, 305	2	16		89, 321
1875	26, 058	74, 357	54	171	3	74, 531
1876	24, 913	55, 443				55, 443
1877	50, 123	111, 494				111, 494
1878	73, 687	230, 041			12	230, 053
1879	31, 779	122, 571				122, 571
1880	104, 703	501, 957	2	12		501, 969
1881	162, 863	336, 998	13	30	648	337, 676
1882	119, 952	213, 311	15	28	1, 266	214, 605
1883	140, 642	162, 036	5	8	5, 972	168, 016
1884	153, 550	173, 251	336	493	(*a*)	173, 744

a Not specified.

BORAX.

Domestic sources.—In addition to the deposits of borates of lime and soda before known to exist in California and Nevada, extensive beds of these minerals have within the past two or three years been discovered in the former State. Of these one is the Death valley, Inyo county; one at Desert Springs, Kern county; and another in the eastern part of the Calico district, San Bernardino county, some of minor importance having been met with elsewhere in these counties. These discoveries have led to the formation of one or two additional companies, and to some new combinations of those before in the field. These new discoveries, companies, and combinations have had the effect of considerably stimulating production, which for the past two years has been large beyond precedent. The total production of borax, all from California and Nevada, has been stated by Dr. Henry Degroot, to whom acknowledgments are due for other material in this paper, in round numbers at 50,000,000 pounds (25,000 short tons), the output in 1883 and 1884 having been 6,500,000 and 7,000,000 pounds respectively.

Price.—Only once before, and then but for a short time, has the price of borax been so low as at present, concentrated being quoted in New York at 8½ cents and in San Francisco at 8 cents per pound, these being the extreme figures for lots of 10 tons or more. For the past two years the price has been steadily tending downwards, and that notwithstanding higher duties have meantime been imposed upon the imported article. The year 1883 opened with the price of borax in New York at 13 cents per pound. After declining to 11 cents, the price on the passage of the new tariff bill advanced 15 cents, but fell back again before the end of the year to 11 cents, by reason of the heavy importations of boracic acid, which had been made in anticipation of a higher tariff. Early in 1884 the price was put down in London 33 per cent., causing a corresponding depression in the markets on this side, the decline having gone on slowly but steadily to the end of the year, when the extreme low figures above stated were reached. The causes that have contributed to so demoralize the market are various, the large production that has been going on of late all over the world being of course the principal one. Among the minor factors which have entered into the problem has been the disposition of English dealers to force down prices with a view to excluding from European markets the product of California. Then there has been the sharp competition between local producers, as well as the similar rivalries elsewhere. There may have been something also in the alleged willingness of the English lessees of the Tuscan salines to unduly depress prices in order to secure a renewal of their leases on more favorable terms. The prospect for any improvement in prices is not very encouraging to the producer. That no advance can take place except through some combination on the part of the principal producers is evident; but how any such concerted action can be brought about where the producing points are so widely separated is not easy to see.

Foreign competition.—While no new uses for this salt, or at least none of much importance, are being introduced, new sources of supply are constantly being discovered. Besides the new deposits of borax found in California, large beds of borate of lime have been discovered lately on the eastern side of the Andes in the State of La Plata, South America, much of this material being rich enough to bear transportation to Liverpool. Chili exported 32,923 quintals of borate of lime in 1883. The discovery of borax in Asiatic Turkey, not far from the Bosphorus, as announced a year or two since, seems also to have been one of considerable magnitude, the French having shipped lately large quantities to Havre. Meantime the exportation of the crude substance from the west coast of South America and from India has gone on actively, while the salines of Tuscany have kept up their usual production; the latest statistics published showing exports of boracic acid from Italy as follows: 1877, 2,697 long tons; 1878, 3,433 tons; 1879, 2,505 tons.

Production.—The production of concentrated borax in California and Nevada during the past ten years has been as follows:

Production of borax since 1875.

Years.	Pounds.	Years.	Pounds.
1875	5, 433, 658	1880	3, 860, 748
1876	5, 180, 810	1881	4, 045, 405
1877	3, 727, 280	1882	4, 236, 291
1878	2, 802, 800	1883	6, 500, 000
1879	1, 584, 966	1884	7, 000, 000

Movement.—The total amount of borax shipped from California and Nevada in 1883 and 1884 was as follows:

Shipments of borax from California and Nevada in 1883 *and* 1884.

To—	1883.	1884.
	Pounds.	*Pounds.*
East by rail	3, 288, 200	2, 995, 880
New York by sea	1, 911, 116	3, 446, 326
Liverpool	1, 287, 777	740, 291
China	20, 231	33, 862
Japan	8, 882	3, 327
Victoria	1, 200	2, 487
Mexico	6, 301	3, 555
Honolulu	4, 200	475
Australia	820	21, 542
Central America	....	200
Antwerp	....	22, 500
Total	6, 528, 727	7, 270, 425

The figures for 1884 showed largely diminished shipments to Liverpool and correspondingly increased shipments to New York, although it has been stated that it is cheaper to ship borax from San Francisco to New York City by way of Liverpool than directly overland. Some dealers adopt this plan, for if there is no market in Liverpool when the borax arrives it can be brought back to New York. A large part of the recent importations has been domestic borax reimported by way of England because of differences in the two markets.

Borax, boracic acid, and borate of lime imported and entered for consumption in the United States, 1867 to 1884 inclusive.

Fiscal years ending June 30—	Refined borax.		Crude borax.		Boracic acid.		Borate of lime.		Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	Pounds		*Pounds.*		*Pounds.*		*Pounds.*		
1867	49,652	$6,601	5,672	$711	770,756	$73,396			$80,708
1868	79,183	10,127	22,293	2,985	243,993	22,845			35,957
1869	89,695	12,799	54,822	8,011	988,033	109,974			130,784
1870	97,078	14,511	2,616	322	1,166,145	173,806	33,529	$1,666	190,305
1871	134,927	20,705	5	1	1,204,049	185,477	45,600	2,248	208,431
1872	35,542	6,288			1,103,974	191,575	22,500	800	198,663
1873	9,284	2,152			1,222,006	255,186			257,338
1874	3,860	1,253	588	78	233,955	52,752			54,083
1875	5,153	1,224			41,742	6,280			7,504
1876	3,145	691			137,518	15,711			16,402
1877	3,500	676	55	12	107,468	11,231			11,919
1878	3,492	514	286	61	178,798	14,925			15,500
1879	3,472	490			306,462	21,888			22,378
1880	15,278	2,011			243,733	18,473	22,122	742	21,226
1881	4,136	865			187,053	15,771			16,636
1882	15,710	3,774			536,334	71,343			75,117
1883	5,611	1,359			4,334,432	580,171			581,530
1884	7,332	1,691	142	34	44,512	4,494			6,219

The imports of boracic acid in 1884 were classed as follows:

	Pounds.	Value.
Commercial	42,900.25	$4,193
Pure	1,611.50	301

Mode of manufacture.—The following description of the Pacific Borax Works, at Fish Lake valley, Esmeralda county, Nevada, is taken from the Candelaria *True Fissure.* The works are the property of F. M. and J. P. Smith, and are new and representative: "There are several large buildings, sheds, platforms, etc., with steam engines and other machinery. The site selected for the works is on the western side of the marsh, and under the side of the hill, high enough to allow a grade sufficient for the handling of the solution from the time the crude borax is first landed on the dump. The crude borax is shoveled into winrows on the marsh and allowed to remain for a time, that the moisture might leave it, decreasing the weight in the matter of hauling. It is then loaded into a wagon and taken to the dump. The side of the hill has been excavated for the building of a stone wall, done in mason work, which is about 15 feet high and 150 feet long. The dump has an easy approach from two sides, and is level enough on the top for the easy handling of all the material taken there. A new building covers the boiler and pumping room, in which is a tubular boiler 16 feet in length and 54 inches in diameter. There are two steam pumps in position, one of which has a 6-inch cylinder, and is used for the purpose of pumping water from the well for washing the tanks and sprinkling, as well as fire purposes. This well is 22 by 12 feet in size and 18 feet deep. The other pump has a 4-inch cylinder, and is used for feeding the boiler and for conveying water to crystallizers. An immense network of steam pipes, of sizes varying from ½ inch to 4 inches in diameter, runs about the pumps and boiler to the dissolving tanks. It is estimated that about 1,500 feet of steam pipe have been put into the places required. Right under the stone wall are six immense iron dissolving tanks, each of which is 9 feet in diameter by 7 in depth. The tops of these are covered with a platform made of 2-inch plank, in which openings are made for filling the tanks. A system of steam pipe extends all over the bottom of each tank, and about every four inches the pipe is perforated for the escape of steam. A quantity of the crude borax is dumped into one or more of the tanks, and about three feet of water added. This fills the tank to within two feet of the top, when the steam is turned on and the mixture receives a thorough boiling. It is allowed to settle ten or twelve hours, and is then drawn off from the top of the solution by a syphon into the crystallizer, located on a platform about 30 feet below. There are forty-five crystallizers now in use, and more will be added when necessary. Each of these is lined with galvanized iron, upon the surface of which the borax precipitates itself, and is easily removed. The solution remaining in the dissolving tanks is then given a second boiling and drawn off again as above described. The mud and remainder of the borax is then turned into a system of mud tanks, which occupy a position immediately below the first line of tanks, and if found to contain a large enough percentage of borax it is shoveled into a car and run along a track to a Hinckley elevator, which lands it on the top again, whence it goes into the dissolving tanks. After the crude borax has been worked over and over until but little remains the tailings are removed to a reservoir made in the ground, just below the last line of crystallizers. This reservoir is 50 feet square and 2½ feet deep, and here the tailings are allowed to remain and undergo the natural changes, the same as when first taken from the marsh. Car tracks run between the lines of mud and the crystallizing tanks and into the drying and storage building. This building is 64 feet long by 24 in width on the ground floor."

The method pursued at Lardarello, Italy, is thus described by Mr. Rice, the American consul at Leghorn: "A shallow pond is dug, and in it an artesian well is bored, which at a small depth invariably strikes the bed of borax. Not content with vapor alone, the boring is carried down till the well gives water. The boring machinery is then withdrawn and the water let into the pond. The upshoot of the boring heats this pond to boiling point in a few minutes, and the boiling in a very short time impregnates the water in the pond with borax, shot up with hot water from the artesian well; there only remains to draw off the water, which is done every twenty-four hours, and evaporize it. This process is effected by passing it over a series of shallow metal pans arranged as a cascade. The fall from one pan to another may be two or three inches, and the pans are fifteen to twenty in number. Underneath the pans are a series of hot steam pipes, which keep the shallow pans at an intense degree of heat, the consequence being that a very large portion of the liquid which reaches the last or bottom pan is semi-solid borax. This is then pumped into vats and allowed to cool, and when cold the vats have the appearance of being frozen over with a thick skin of very dirty and rotten ice. This skin is removed and strewed on the floor of a drying house, heated by hot pipes under the floor, and by this means the borax becomes crystallized. The boracic acid is then ready for packing, the color not being the same in all cases, varying from a dirty white to almost black. The acid is mixed in the stores and packed in huge casks, weighing fourteen to sixteen hundredweight, for exportation. The lagoons are most interesting to watch. When full of water the boiling is continuous, rising (especially in the case of the artesian borings) to some feet in height. When natural springs, the bubbles are about a foot above the level of the water. The vapor is, however, most clammy, and especially unpleasant from its excessive sulphurous odor. When the water is pumped out the bottom of the lagoon remains of a dirty mud color, with round, semi-spherical holes like pock-marks, varying from a foot to several feet in diameter and depth; these are the springs. When empty they each give off a small amount of vapor, but as water finds its way into the holes in question ebullition commences, and each hole appears to be a cooking pot, boiling with all its might, the water rising more and more, the lagoon one huge boiling caldron. The difficulty in the production, and a very grave difficulty it is, consists in the scarcity of water; in fact, in the summer Lardarello is almost the only establishment that can work satisfactorily, and even at Lardarello the works are often working half time only. The water which has served in the mineral baths at Morbo is carefully drained down to the Lardarello reservoir and there stored."

SULPHUR.

By David T. Day.

Occurrence.—The sulphur springs found so frequently through the United States bear evidence to the general distribution of sulphur either in the free state or in combination with hydrogen. Beds of sulphur occur in the following localities in the eastern States: At Cayuga lake and at Springport, Cayuga county, New York; twenty-five miles above Washington, on the Potomac river, Virginia; at Put-in Bay island, Ohio; in Kansas; at Tampa, Florida; and in Louisiana. These deposits are too small to have any industrial significance, except the beds in Louisiana. Here sulphur is found thirteen miles from Lake Charles, Calcasieu parish, near the track of the New Orleans and Texas railway. In 1869 and 1871 a number of borings were made showing that the bed is reached at about 425 feet from the surface; the sulphur layer is said to average 100 feet in thickness and to be quite pure. Under it is a bed of gypsum and sulphur (principally the former) about 150 feet thick. The first company incorporated to work the deposit was composed chiefly of French creoles headed by Gen. Jules Brady. After sinking a sectional cast-iron shaft to a depth of 110 feet the enterprise was abandoned on account of the breaking of the lining. The property is now owned by a company, with Mr. Duncan F. Kramer at its head; it has done little, however, towards mining the deposit. Mr. D. M. Jewett, of White Oak, New Mexico, reports sulphur deposits in Tom Green county, Texas, which might prove valuable if mined.

The only important beds of sulphur from the present point of view are in the far West. In Wyoming it occurs in quite large quantities about 30 miles southeast of Evanston, in the Uintah mountains, Uintah county. Large beds are said to occur in the southeastern part of Idaho, near Swan lake, and also four miles from Soda springs, Oneida county. Sulphur is found in several localities in New Mexico. In California it is found in the Azur mountains, on the border of Santa Barbara and Ventura counties; in the Coast range, 30 miles west from the town of Colusa; on Chalk mountain, two miles east of Clear lake, Lake county; at various places in Napa, Kern, San Luis Obispo, Los Angeles, and San Bernardino counties, and about the mud volcanoes in San Diego county. Although some of these deposits are large, none except that at Clear lake has been utilized, and they will probably long remain untouched on account of the difficulty of bringing the sulphur to market at prices comparable with Sicilian sulphur. At the Clear lake deposit sulphur occurs in a decomposed volcanic rock. Through fissures in this rock steam and vapor of sulphur compounds issue and deposit sulphur near the surface, where it is found mixed with 10 to 35 per cent. earth, silica, etc. A curious feature of this deposit is the occurrence of a notable percentage of cinnabar mixed with the sulphur; and borax is also found in the neighborhood. In 1864 an extensive refinery with a capacity of 6 tons per day was erected here, and for about twenty years was used in turn for borax, sulphur, and quicksilver. The crude sulphur was shoveled into wheelbarrows and thrown into a furnace, from which it passed into a receiver, thence into large iron kettles, where it was purified, and was finally cast in molds. From 1865 to 1868, inclusive, about 2,000,000 pounds of sulphur were produced, but at the end of that period the enterprise was abandoned as unprofitable, principally because the price of refined sulphur in San Francisco had fallen from $75 to $40 per ton.

In Nevada sulphur has been found near Humboldt House, Humboldt county, in the craters of extinct hot springs on the open sage-brush desert. Nearly all the cones, which rise to the height of 20 to 30 feet, are weathered and broken down; the outer surface is composed of calcareous tufa and siliceous sinter forming irregular sheets sloping away at a low angle from the orifice at the top. The interiors are filled with crystalline gypsum containing, at least in two cases, sulphur. One of the cones has been opened by a cut in the side in such a manner as to expose a good section of material filling the interior, and a few tons of the sulphur and gypsum have been removed. The percentage of sulphur is small; and, according to Mr. I. C. Russell's report, read to the New York Academy of Sciences, the economic importance of the deposit, as shown by the excavation already made, will not warrant the further expenditure of capital. Sulphur is reported as occurring in the deposits surrounding Steamboat springs, situated midway between Carson and Reno; in the Sweetwater mountains, on the boundary between California and Nevada, in latitude 38° 30′; again 10 miles north of the Humboldt salt marsh in Churchill county there is a bed covering 30 acres, and some of the sulphur is said to be quite pure, though the greater part is mixed with a large percentage of earth, etc. These localities have not been mined. The most important sources of sulphur in the United States at present are the Rabbit-hole mines in northwestern Nevada, on the eastern border of the Black Rock desert, deriving their name from the Rabbit-hole springs, a few miles to the southward. The hills bordering the Black Rock desert on the east are, according to Mr. Russell, mainly of rhyolite, with a narrow strip of volcanic tufa along the immediate edge of the desert. These beds of tufa are stratified and have evidently been deposited by water, and are identical with tufa deposits that occur over an immense area in Oregon and Nevada. At the sulphur mine the tufa is richly charged with sulphur, which fills all the interstices of the rock and sometimes lines cavities 5 or 6 feet wide with layers of crystals. In the Rabbit-hole district sulphur has been found in paying quantities for a distance of several miles along the border of the desert; but the distribution is irregular and is always superficial, so far as can be judged from the present openings. The sulphur has been derived from a deep-seated source and deposited from the condition of vapor, among the cooler and higher rocks where it is now found. A valuable portion of the beds belongs to the Humboldt Sulphur Company. In 1865 this company erected works on the ground for refining sulphur. Previous to this time the company had shipped some crude sulphur to San Francisco. The works have a capacity of 20 tons per day, and have produced as much as 1,200 tons a year, employing twenty men all the year. The sulphur, after being mined and assorted, is placed in upright cast-iron retorts having a general resemblance to the common form of blast furnace, with a capacity of about 2½ tons each. When the retorts have been charged, the opening at the top is closed and superheated steam is admitted at the side. When the sulphur melts it passes through a grate and is collected in a kettle beneath the retort, from which it flows into a receiving pan holding 6 tons; here the impurities settle off and the sulphur is cast into blocks, which are sold in San Francisco for $40 to $45 per ton. In spite of an expenditure of $60,000 to $70,000 in the plant and unusually heavy running expenses due to the barrenness of the country, refining would continue profitable if these prices could be assured, but it seems possible for the Sicilian producer to run the price much lower, and this competition has nearly stopped the works.

In Utah it is said that the Mormons refined sulphur from native ore thirty years ago. About fifteen years ago prospecting was begun in the Gordon mining district, in the southeastern part of Millard county, by Mr. C. A. Semler; this resulted in the discovery of extensive sulphur beds at Cove Creek, about 22 miles east of Black Rock, on the Utah Central railroad. In 1870 the Cleveland mine was located, and in 1872 fourteen others—the Mammoth, Philadelphia, Prince Albert, Mariposa, Excelsior, New York, Sulphur King, Queen Victoria, Brooklyn, Boston, Victor, Hoosic Falls, Utah, and Conqueror. A few of these claims have been developed to a slight extent. They have not yet been worked sufficiently, however, to make the sulphur from this locality an article of commerce. Mr. Russell thus describes the mines: "The deposits at Cove Creek arrange themselves in three convenient groups, the divisions depending, however, more on the nature of the cavities that have received the sulphur than on any difference in the manner in which it has been introduced. In one instance the sulphur occupies a nearly extinct solfatara; again we find it impregnating and cementing beds of volcanic tufa; at other places the sides of fissures are sheathed with a brilliant drusy lining of sulphur crystals. In all of these instances it is evident that the sulphur has been derived from deeply-seated sources, having been expelled in a gaseous form and condensed and crystallized in the cavities and fissures in the cooler rocks. In the mine named the Cleveland by Mr. Semler, which is situated about 2 miles southward of the fort at Cove Creek, the sulphur occurs in quantity, filling the crater of a solfatara. The bottom of the little valley in which the Cleveland is situated is nearly circular, with a diameter of about 1,200 feet, and is totally destitute of vegetation; over the level surface of this desert the sulphur outcrops in many cases, forming ledges; a number of prospects show an abundance of quite pure material. A shaft was sunk in the center of this deposit to the depth of 25 feet, all in pure sulphur. The material taken from the shaft was returned to it in order to guard against burning the mine, and the broken fragments are now cemented into a solid mass by the sulphur that has been deposited in the interstices between them. The deposition of sulphur is still in progress, the prospect holes becoming lined in a few days with most beautiful crystals of pure sulphur. The sulphur at this locality covers a circular area about 1,000 feet in diameter, and from the prospects that have been reported cannot be less than 25 feet thick. This is not pure sulphur, but carries a large percentage of earthy matter. Of the second class of mines—those in which sulphur impregnates beds of volcanic tufa—we have examples in the Mariposa and Prince Albert mines, situated at the base of the mountain 2 miles east of the fort at Cove Creek. At these localities the tufa is stratified; it contains scattered pebbles of quartzite and limestone, and is impregnated over a large area with sulphur, which fills all the interstices of the rock. Judging by the eye alone, much of the tufa contains from 10 to 40 per cent. of sulphur, while in some localities the rock is far richer than this. Over the tufa are alluvial cones of gravel, that are in some places cemented by sulphur in the same manner as the strata of tufa beneath, thus showing that the beds now carrying sulphur have acted simply as condensers for the sulphur, which in every case has been derived from a deeper source. The third class of sulphur deposits—those in which the sulphur forms a lining of crystals on the sides of fissures—are illustrated by the Philadelphia and Mammoth mines. At the first of these, situated 1 mile north of Cove Creek, the sulphur occurs in drusy crystals covering the sides of small intersecting fissures in trachyte. The Mammoth is of similar character, but found in dark Carboniferous limestone." Up to 1880 only sufficient work had been done on these deposits to hold title to the mines, but considerable money has lately been invested in plant for refining sulphur, and daily shipments are being made to Salt Lake City.

In Alaska heavy deposits of sulphur are found near the volcanic cones abundant on the Onimak, Kodiak, Unalaska, and Aleutian groups of islands, where the sulphur has long been used by the natives as a means for producing fire. The deposits have never been otherwise utilized.

Production.—During 1883 and 1884 the mining of American sulphur has nearly ceased; 1,000 tons in 1883 and 500 tons in 1884 will cover the production, which came principally from the Rabbit-hole mines in Nevada. About half of the supply for 1883 was sent to San Francisco, the rest being consumed locally, in the acid works at Dayton. A small proportion was produced in Utah, finding use in Salt Lake City as a sheep dip and in local acid works. It is probable that the Utah deposits will furnish larger quantities during 1885.

Price.—The price of crude sulphur has declined from $27 per long ton (2,240 pounds) for "best unmixed seconds" in 1883, to $23.50 at the close of 1884. In fixing this price little regard is paid to the source of the sulphur, but it is based on the distinction between that part of calcarone sulphur which has a bright yellow color, which is called "seconds," and that with a dirty brown color, which is called "thirds" and is usually sold for 75 cents less per ton. The brown variety is usually nearly as pure as "seconds," but occasionally contains as much as 6 per cent. impurities, frequently gypsum. The small amounts of Japanese sulphur received in America have been classed as "best unmixed seconds," but a cargo of 3,000 tons was sold in 1883 at San Francisco for $20.75 per ton. The price of refined sulphur has been $40 to $45 per ton during 1883 and 1884.

Foreign sources.—The one important source of sulphur is the island of Sicily. The Sicilian deposits have frequently been described, and are treated at considerable length in A. W. Hoffman's "Entwickelung der chem. Industrie." The yearly production in Sicily increased from 143,323 tons in 1862 to 171,236 tons in 1871, and the entire production of Italy for three years is given below. Nearly all of this is from Sicily:

Sulphur produced in Italy for three years ending 1879.

Years.	Quantity.	Value.
	Tons.	
1877	260, 325	$5, 372, 344
1878	305, 142	6, 110, 534
1879	376, 316	7, 291, 607

Sulphur is also produced in Japan, China, India, Turkey, Austria-Hungary, Spain, the Sunda and Philippine islands, and in Iceland. Occurrences have been noticed also in France, Suez, and Tripoli, but are not mined.

Imports.—Sulphur is imported principally from Sicily; occasional cargoes are received in San Francisco from Japan, amounting to less than 3,000 tons per year. The latest accounts (June, 1885) are to the effect that 2,000 tons have just been received at New York from Japan; as much more is on the way, and negotiations are active for further shipments. The following table gives the imports of sulphur of various grades since 1867.

Sulphur imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Crude.		Flowers of sulphur.		Refined.		Ore. (*a*)	Total value.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Value.	
	Long tons.		*Long tons.*		*Long tons.*			
1867	24, 544. 10	$620, 373	110. 05	$5, 509	250. 55	$10, 915	....	$636, 797
1868	18, 150. 55	446, 547	16. 48	948	64. 75	2, 721	....	450, 216
1869	23, 589. 69	678, 642	96. 59	4, 576	645. 04	27, 149	....	710, 367
1870	27, 379. 60	819, 408	76. 34	3, 927	157. 24	6, 528	$1, 269	831, 132
1871	36, 131. 46	1, 212, 448	65. 54	3, 514	92. 26	4, 328	754	1, 221, 044
1872	25, 379. 55	764, 798	35. 97	1, 822	56. 94	2, 492	....	769, 112
1873	45, 533. 27	1, 301, 000	55. 29	2, 924	35. 97	1, 497	....	1, 305, 421
1874	40, 989. 55	1, 260, 491	51. 08	2, 694	56. 68	2, 403	....	1, 265, 588
1875	39, 683. 10	1, 259, 472	17. 83	891	....	....	....	1, 260, 363
1876	46, 434. 72	1, 475, 250	41. 07	2, 114	43. 87	1, 927	....	1, 479, 291
1877	42, 962. 69	1, 242, 888	116. 34	5, 873	1, 170. 80	36, 962	....	1, 285, 723
1878	48, 102. 46	1, 179, 769	158. 71	7, 628	149. 51	5, 935	....	1, 193, 332
1879	70, 370. 28	1, 575, 533	137. 60	6, 509	68. 94	2, 392	....	1, 584, 434
1880	87, 837. 25	2, 024, 121	123. 70	5, 516	158. 36	5, 262	....	2, 034, 899
1881	105, 096. 54	2, 713, 485	97. 66	4, 226	70. 96	2, 555	....	2, 720, 266
1882	97, 504. 15	2, 627, 402	158. 91	6, 926	58. 58	2, 196	....	2, 636, 524
1883	94, 539. 75	2, 288, 946	79. 13	3, 262	115. 33	4, 487	....	2, 296, 695
1884	105, 112. 19	2, 242, 697	178	7 869	126	4, 765	....	2, 255, 331

a Latterly classed under head of pyrites.

Statement by countries and by customs districts, showing the imports into the

[Quantities expressed in long cwts.]

Countries whence exported and customs districts through which imported.	1875.		1876.		1877.		1878.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
COUNTRIES.								
Austria	......	....	......	....	3, 320	$7, 098	......	....
Belgium	......	....	......	....	......	....	2, 590	$5, 242
Brazil	......	....	......	....	246	833	......	....
England	2	$36	371	$914	298	806	168	469
Scotland	......	....	338	683	214	427	......	....
France	533	1, 363	1, 666	4, 071	4, 577	10, 780	3, 850	9, 174
Germany	......	....	......	....	......	....	......	....
Italy	......	....	......	....	16, 800	22, 720	20	39
Japan	......	....	......	....	3, 584	6, 204	......	....
Total	535	1, 399	2, 375	5, 668	29, 039	48, 868	6, 628	14, 924
DISTRICTS.								
Boston & Charlestown, Massachusetts	......	....	......	....	......	....	......	....
New York, New York	20	42	338	683	21, 170	32, 348	76	166
Philadelphia, Pennsylvania	......	....	......	....	......	....	2, 590	5, 240
San Francisco, California	515	1, 357	2, 037	4, 985	7, 869	16, 520	3, 962	9, 518
Total	535	1, 399	2, 375	5, 668	29, 039	48, 868	6, 628	14, 924

a The total imports entered for consumption in the United States in the fiscal year 1884 were 3,560 "refined sulphur," valued at $4,765.

Statement by countries and by customs districts showing the imports into the United

[Quantities expressed in long tons.]

Countries whence exported and customs districts through which imported.	1875.		1876.		1877.		1878.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
COUNTRIES.								
Austria	25	$973	......	....	......	....	......	....
Dutch West Indies and Dutch Guiana	......	....	1, 515	$15, 427	......	....	......	....
England	48	1, 966	30	1, 211	425	$14, 631	(?)	$16
Scotland	......	....	24	910	472	13, 231	160	3, 961
Gibraltar	......	....	......	....	290	7, 789	......	....
Quebec, Ontario, Manitoba, and the Northwest Territory	......	....	......	....	......	....	12	264
France	......	....	......	....	......	....	......	....
French West Indies	......	....	......	....	......	....	......	....
Greece	......	....	......	....	......	....	......	....
Italy	38, 907	1, 236, 202	46, 941	1, 439, 839	41, 819	1, 194, 000	47, 494	1, 161, 367
Japan	604	15, 959	456	16, 291	437	13, 137	256	7, 548
Portugal	......	....	......	....	......	....	......	....
San Domingo	......	....	......	....	......	....	......	....
Spain	......	....	......	....	......	....	......	....
Spanish Possessions in Africa and adjacent islands	......	....	......	....	......	....	......	....
Total	39, 584	1, 255, 100	48, 966	1, 473, 678	43, 443	1, 242, 788	47, 922	1, 173, 156
DISTRICTS.								
Baltimore, Maryland	3, 000	98, 900	5, 157	157, 828	3, 882	105, 175	5, 455	138, 202
Barnstable, Massachusetts	......	....	......	....	......	....	......	....
Beaufort, South Carolina	......	....	......	....	......	....	......	....
Boston & Charlestown, Massachusetts	5, 222	168, 129	5, 031	154, 883	3, 931	101, 215	5, 795	131,945
Charleston, South Carolina	......	....	......	....	......	....	526	12, 267
Delaware, Delaware	......	....	450	13, 500	......	....	......	....
Huron, Michigan	......	....	......	....	......	....	12	264
Middletown, Connecticut	......	....	......	....	......	....	......	....
Newark, New Jersey	......	....	......	....	1, 071	31, 802	462	13, 240
New Orleans, Louisiana	......	....	172	5, 705	150	4, 750	......	....
New York, New York	23, 313	740, 494	24, 524	721, 092	21, 867	654, 997	28, 240	690, 989
Philadelphia, Pennsylvania	6, 148	188, 733	12, 549	385, 071	9, 216	256, 224	6, 657	167, 222
Providence, Rhode Island	1, 251	40, 994	600	18, 232	1, 739	45, 487	519	11, 479
Richmond, Virginia	......	....	......	....	......	....	......	....
San Francisco, California	650	17, 850	483	17, 367	862	27, 768	256	7, 548
Savannah, Georgia	......	....	......	....	725	15, 370	......	....
Total	39, 584	1, 255, 100	48, 966	1, 473, 678	43, 443	1, 242, 788	47, 922	1, 173, 156

United States of refined sulphur each fiscal year, from 1875 *to* 1884 *inclusive.*

[Quantities expressed in long cwts.]

1879.		1880.		1881.		1882.		1883.		1884(*a*).	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
......	....	......	....	......	....	......	....	......	....	......	....
......	....	......	....	201	$389	......	....	212	$473	......	....
......	....	......	....	......	....	......	....	......	....	......	....
352	$693	624	$1,169	397	763	388	$862	495	1,089	......	....
......	....	......	....	......	....	......	....	......	....	......	....
4,774	10,270	2,556	4,361	2,354	4,728	5,901	11,333	1,708	3,357	......	....
......	....	......	....	......	....	106	254	97	231	......	....
......	....	......	....	120	241	1,496	3,202	......	....	......	....
......	....	......	....	......	....	......	....	......	....	......	....
5,126	10,963	3,180	5,530	3,072	6,121	7,891	15,651	2,512	5,150	......	....
......	....	440	671	......	....	......	....	......	....	......	....
915	1,534	10	30	322	635	16	122	5	16	......	....
......	....	......	....	......	....	......	....	......	....	......	....
4,211	9,429	2,730	4,829	2,750	5,486	7,875	15,529	2,507	5,134	......	....
5,126	10,963	3,180	5,530	3,072	6,121	7,891	15,651	2,512	5,150	......	....

long hundredweights of "flowers of sulphur," valued at $7,869; and 2,520 long hundredweights of

States of crude sulphur or brimstone each fiscal year, from 1875 *to* 1884 *inclusive.*

[Quantities expressed in long tons.]

1879.		1880.		1881.		1882.		1883.		1884(*a*).	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
......	....	......	....	......	....	......	....	......	....	......	....
......	....	......	....	......	....	......	....	......	....	......	....
2	$335	1	$22	......	....	......	....	13	$379	......	....
806	19,287	1,664	36,444	1,668	$43,311	755	$20,294	3	88	......	....
......	....	......	....	......	....	......	....	......	....	......	....
......	....	......	....	......	....	......	....	......	....	......	....
......	....	988	23,580	......	....	526	13,770	34	858	......	....
......	....	......	....	......	....	2	8	......	....	......	....
......	....	......	....	......	....	500	13,927	......	....	......	....
64,420	1,453,138	80,301	1,862,712	102 771	2,645,293	92,944	2,504,862	92,861	2,248,870	......	....
224	4,528	282	4,744	691	16,253	2,980	66,356	1,038	23,714	......	....
467	10,410	......	....	......	....	......	....	......	....	......	....
......	....	......	....	......	....	240	7,875	......	....	......	....
......	....	......	....	308	8,637	......	....	500	12,856	......	....
......	....	......	....	......	....	9	310	87	2,030	......	....
65,919	1,487,698	83,236	1,927,502	105,438	2,713,494	97,956	2,627,402	94,536	2,288,795	105,143	$2,242,678
6,969	157,243	13,827	313,342	16,477	430,917	13,781	364,384	11,977	286,438	15,037	303,226
600	13,780	......	....	......	....	......	....	......	....	650	16,163
......	....	......	....	......	....	540	13,889	......	....	600	13,259
7,841	173,506	8,207	183,486	8,860	226,801	7,467	194,317	7,756	173,569	5,294	112,152
605	13,812	1,061	25,398	3,065	78,741	6,025	161,281	4,051	106,235	6,125	132,570
890	21,907	......	....	......	....	......	....	......	....	......	....
......	....	......	....	......	....	......	....	......	....	......	....
......	....	......	....	......	....	9	310	......	....	......	....
443	10,175	......	....	......	....	......	....	......	....	......	....
100	2,087	280	7,121	100	2,646	220	6,516	428	10,378	......	....
36,543	827,193	46,657	1,083,784	57,608	1,463,082	46,531	1,260,222	45,385	1,110,313	52,478	1,135,725
11,704	263,467	10,679	254,892	17,987	477,547	14,839	408,611	22,772	549,095	18,786	401,468
......	....	1,255	31,155	650	17,507	1,244	33,036	535	13,830	651	15,517
......	....	......	....	......	....	660	17,760	......	....	......	....
224	4,528	1,270	28,324	691	16,253	6,054	151,234	1,072	24,572	5,522	112,598
......	....	......	....	......	....	586	15,842	560	14,365	......	....
65,919	1,487,698	83,236	1,927,502	105,438	2,713,494	97,956	2,627,402	94,536	2,288,795	105,143	2,242,678

a Sources not reported.

The foregoing tables show the distribution of the imported sulphur, as well as the sources from which it came. The refined sulphur imported from England and France is of Sicilian origin, which is simply refined in other countries. The imports of crude sulphur from England, Scotland, and France are principally reshipments of Sicilian sulphur.

In addition to the above amounts, some lac sulphur, or "precipitated" sulphur, is imported for pharmaceutical purposes, as shown in the following table:

Lac sulphur imported and entered for consumption in the United States, 1879 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.
	Pounds.	
1879	10, 012	$880
1880	13, 903	1, 238
1881	....	775
1882	28, 217	2, 137
1883	30, 197	2, 072
1884	36, 083	2, 954

Extraction of sulphur from its ores.—It is customary in the few American refineries to extract sulphur from the earth and other foreign matter with which it may be mixed by heating the "ore," as this mixture is called, either in large retorts or, more frequently, by superheated steam in furnaces somewhat like a blast furnace. The sulphur melts, is collected at the bottom of the furnace, and is run into settling tanks, where it is kept melted until the slight impurities settle off. As the comparative cost of refining sulphur in this country and in Sicily is the vital point in the competition which must ensue before American sulphur can gain footing in the general market, it is useful to compare the above methods with those which have been in use for many years in Sicily. Such a comparison is aided by the admirable translation by Mr. W. S. Bailey, for the *American Chemical Journal*, of Vincent's paper upon the extraction of sulphur. In Sicily, as in the western part of this country, scarcity of fuel is one of the difficulties. The earliest method adopted to overcome this in Sicily consisted in using sulphur itself as a fuel for heating more sulphur until it melts and runs out of the mass of earth, gypsum, etc., with which it is mixed. The ore was piled in a stack 6 to 15 feet square over a ditch 3 to 4 inches deep with its bottom beaten hard and sloping to a single point, permitting the sulphur to flow out through an opening called the "morto." In building the stack care was taken to put the largest pieces of ore at the bottom, diminishing the size toward the top. The construction of the stack usually occupied two days. On the evening of the second it was ignited. The heat of the burning sulphur caused that part of it to which the air had no access to melt and run out through the opening at the bottom. On the fourth day the operation was complete and the stack pulled down. By this so-called "calcarelli" method 385 pounds of sulphur were obtained from

6,700 pounds of ore, or 5.7 per cent. from ore containing from 25 to 45 per cent.; 1,960 pounds of sulphur were burned as fuel in order to furnis 385 pounds of sulphur. In 1850 this process was markedly improved by changing the calcarelli into "calcaroni." The latter are, as the form of the word indicates, similar to calcarelli, but on a much larger scale and better plan. A hole 30 feet in diameter and about 8 feet deep, so arranged (usually in the side of a hill) that an opening can be made at the lower side, is walled up with gypsum and made sulphur-proof by a coating of plaster-of-paris. The bottom slopes down the hill. Within this wall the sulphur ore is built up in the form of a dome, and covered with a layer of spent ore. Holes are left at appropriate intervals for the draft, which must be regulated with the greatest care to secure the best yield of sulphur. The calcaroni are built to last ten years, and have a capacity of from 50 to 500 "cassa" (a cassa = 2.5 to 5 tons). The calcarone is lighted by dropping burning straw and sulphur into the openings. It is allowed to burn for an hour and then all the openings are closed for eight to nine days. About this time mixed vapors, consisting of water, sulphur, and sulphur dioxide begin to make their way out of the heap, and a deposit of sublimed sulphur is found near the closed draft holes. At the same time the tap at the bottom becomes hotter until it is red hot. By opening the taphole the workmen observe whether a considerable amount of melted sulphur has collected. In some works the sulphur is allowed to collect until the operation is finished and is then drawn off and cast; but at most places it is drawn off twice or thrice every twenty-four hours. The length of time consumed in the whole process varies with the capacity of the calcarone, the nature of the mineral, and the atmospheric conditions; being slower as the ore is harder and the atmosphere colder. Small kilns usually require from thirty to thirty-five days and large ones eighty to ninety days. The proportion of sulphur burned in this process is variable and depends upon many conditions. It is particularly large when the ore contains much gypsum (consequently considerable water), or when it is brought into the oven in a moist condition, or when there is a heavy rainfall during the burning. With long-continued rains it sometimes happens that all the sulphur is consumed. In a well-conducted operation, with an ore containing 25 per cent. sulphur, 70 per cent. limestone and gangue, and 5 per cent. water, one-fifth of the sulphur should suffice, according to theory, to melt out the other four-fifths; in practice, one-third to two-fifths is required.

It scarcely needs to be stated that numerous methods have been proposed for avoiding this waste of sulphur, and more particularly the great damage to agriculture in the surrounding country. So great is this nuisance that the Italian Government forbids "burning the ore" between July 1 and December 31. Heated air, steam under pressure, superheated steam, and various solvents have been in turn proposed for the purpose of obtaining the greater part of the sulphur without the production of sulphurous fumes. In the heated-air process a chamber of masonry is filled with the ore, and a current of warm gas from a hearth fed with wood or coal is sent into it. This prevents in a great measure the production of sulphurous acid, but the action is slow and the mass of ore is irregularly heated. A large amount of fuel is used and the number of employés increased, so that the economy over the old method is slight. The use of superheated steam, as carried on in Nevada, seemed at first to offer the best solution of the problem, for its action is very simple and rapid, and the sulphur obtained is of good quality. The yield is better than in the calcarone process, and no sulphur dioxide is produced. In a country where fuel is cheap there is little doubt but what this process would be advantageous, but in a region like the Rabbit-hole district in Nevada experience will probably show, as it has already done under very similar conditions in Sicily, that the advantages are counterbalanced in great part by the extra expense of purchasing and maintaining the equipment, as well as furnishing the fuel. The necessary apparatus consists of boilers for generating the steam, tanks to receive the ore, and the other accessories. The proportion of fuel used is considerable, in consequence of the large amount of steam necessary to heat the ore, and of waste by radiation from a large surface of tanks and boilers. The extraction by dissolving sulphur in carbon bisulphide and regaining the solvent by distillation is inconvenient because of the very great care needed in the arrangement and running of a necessarily complicated plant. These difficulties have prevented the use of such processes in Italy to any great extent, so that the old method of the calcarone is still generally employed. But within the last year or two another method of extraction has been found so applicable to the conditions of Sicilian sulphur mining that it is hoped that it may also be valuable under analogous conditions in America. The method consists in melting the sulphur in a bath of water containing so much calcium chloride that it can be heated to the melting point of sulphur without boiling. In 1805 Thomas proposed immersing the ore in salt solutions heated to a suitable temperature. Balard, in 1867, thought the water from the salt marshes, which is rich in magnesium chloride, might answer. Finally, in 1868, Deperais took out a patent in Italy for the extraction of sulphur by the immersion of its ores in a liquid heated to 10° to 20° C. above the fusing point of sulphur. By this means it is separated from the earthy substances associated with it. He used a solution of calcium chloride. The apparatus consisted of a spherical boiler of 2,000 liters capacity, furnished with a stopcock for drawing off the liquid sulphur, and surmounted by a vertical cylindrical part, into which, with the aid of a pulley, a basket of perforated iron, filled with the ore, can be let down upon a grate. The apparatus is placed in a furnace and heated directly, while the cylindrical portion is surrounded by the warm products of combustion as they go up the chimney. The basket of ore is let down into the solution of calcium chloride heated to

130° C. The sulphur melts, collects at the bottom of the boiler, and is drawn off by the stopcock and poured into molds. When the ore is exhausted the basket is raised and immediately immersed in water contained in another boiler heated by the same furnace; this water is used to supply the place of that evaporated in the first boiler. At the time when this process was introduced calcium chloride was comparatively dear, so that the patent could not be worked successfully and was soon abandoned. Very recently it has been taken up again by MM. de la Tour and Dubreuil and put into successful use. Calcium chloride is now very cheap, in consequence of the rapid development of the soda industry (the ammonia process). It can be put down at the sulphur mines in Sicily at 9 francs per 100 kilograms. The apparatus of MM. de la Tour and Dubreuil consists of two rectangular tanks 6½ by 4⅓ by 2½ feet. The bottom is inclined 1:10. They are placed in the same furnace, and heated alternately by the same fire, which is fed with coke, lignite, or coal. The ore is placed in one of these tanks, in which is also placed a solution of calcium chloride boiling at 120° C. Heat is then applied. The sulphur melts gradually and is drawn off directly into molds by means of a spigot. The whole operation lasts about two hours. The end is reached when the sulphur ceases to flow. The calcium chloride solution is then drawn off into the other tank previously charged with ore. Half the liquid flows through a communicating tube; the rest is received in a vat built in the ground and is raised by a pump. The gangue is washed to regain the salt which it has absorbed, and this dilute solution is used in filling the tanks as occasion demands. The heat is then directed upon the second tank, and the first is cleared and recharged. There is no interruption in the work and the heat from the fire is all utilized. The sulphur obtained contains only 0.1 to 0.2 per cent. of impurities, while that obtained from the calcaroni contains from 2 to 3 per cent. There is left in the gangue but 4 to 5 per cent. of the sulphur originally contained in the ore. In this treatment certain ores are completely disintegrated, in consequence of the fusion of the sulphur, which then contains earthy matter. The following form of apparatus is, however, applicable to all kinds of ores. The tanks are horizontal, and are divided longitudinally through the center by a gutter with inclined sides, which collects the sulphur, and from which it is drawn. On its sides iron gratings are built vertically to keep the ore from falling into it. These gratings are made of bars of sheet iron $\frac{1}{12}$ inch thick and 1 inch wide, placed $\frac{1}{16}$ inch apart. By this arrangement even the fine powder formed in mining can be treated. This powder, known as "sterri," is always richer than the average ore, because in getting out the ore the rock breaks along the lines of least resistance, which in this case are the veins of sulphur. On account of its friability the sulphur is reduced partially to dust and forms a large part of the mixture.

At the Tronica mine, in the Caltanisetta district, in Sicily, the ordinary ore gives 21 per cent. sulphur by the calcium chloride method, and only 12 to 13 per cent. when treated in the calcaroni. After the treatment of a large amount of sterri, MM. de la Tour and Dubreuil estimated the cost of extraction of a ton of sulphur at 12¾ francs in the case of a mean yield of 33 per cent. of the weight of the ore. It seems possible that this method might give satisfactory results in this country, where some other salt might be substituted for calcium chloride, if the shipment of this from England should make it too expensive.

Utilization.—A comparatively small quantity of sulphur is used in the manufacture of gunpowder; sulphur compounds, such as carbon bisulphide, for protecting California vineyards from mildew; and in the manufacture of ultramarine in Newark, New Jersey. There was formerly a small consumption of Nevada sulphur in the chloridizing-roasting of silver ores; but in the few cases in which sulphur is needed to effect the reactions, it is now added in the form of copperas. Nearly all the sulphur is now used for making sulphuric acid. It is difficult to estimate the total amount of this substance produced each year, but it is estimated that 306,000 short tons of sulphuric acid were made in 1884 from crude sulphur, and about 122,000 tons from pyrite. The only noteworthy improvement in the manufacture of sulphuric acid has been in the direction of using pyrite as the source of the sulphur, and a discussion of this subject will be found in Mr. Martyn's paper on pyrites, immediately following this section. A small amount of common sulphuric acid and some fuming sulphuric acid are imported for special purposes, according to the following table:

Sulphuric acid imported and entered for consumption in the United States, 1867 *to* 1883 *inclusive.*(*a*)

Fiscal years ending June 30—	Commercial sulphuric acid.		Fuming (Nordhausen) acid.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1867	1,327	$95	....	....	$95
1868	516	54	....	....	54
1869	20,870	1,140	....	....	1,140
1870	2,049	119	....	....	119
1871	8,509	642	....	....	642
1872	572	71	....	....	71
1873	200	19	....	....	19
1874	82,555	2,062	....	....	2,062
1875	18,000	360	....	....	360
1876	12,160	280	202	$24	304
1877	148	5	....	....	5
1878	40	3	312	23	26
1879	165	10	1,157	123	133
1880	10,730	333	2,725	229	562
1881	786	23	3,055	238	261
1882	1,386	63	8,350	824	887
1883	22,320	2,656	7,633	783	3,439

a Not specified in 1884.

PYRITES.

By William Martyn.

OCCURRENCE IN THE UNITED STATES.

New Hampshire.—From this State comes an excellent ore, admirably adapted for acid making, and in this respect comparing favorably with the best Spanish ores. It is mined at Milan, in Coos county. The shaft is close to the Grand Trunk railway, connection with which is made by a short tramway. The vein is 15 to 25 feet wide. In addition to the ore sold to sulphuric-acid makers, large quantities of ore carrying a fair percentage of copper and silver are mined, and this is picked out from the other and smelted at the mine, the resulting argentiferous copper matte being shipped to New York to be refined. The proportion of the different grades of ore is said to be as follows:

	Per cent.
Marketable ore for acid works	75.00
Copper ore for smelting	10.00
Smalls	10.00
Waste	5.00
	100.00

The composition of Milan No. 1 ore is about as follows:

	Per cent.
Sulphur	48.0
Iron	43.0
Copper	1.6
Zinc	1.5
Silica	5.0
Arsenic	traces.
	99.1

The ore is compact, burns readily without making any clinker, and requires a minimum of attention to insure thorough desulphurization. Milan No. 2 ore contains less sulphur and more zinc than the above. The latter metal (which is sometimes present to the extent of 11 per cent.) often prevents the recovery of a fair proportion of the sulphur of the ore, owing to the formation of sulphate of zinc, which requires a higher temperature for its decomposition into sulphuric anhydride and oxide of zinc than the sulphates of copper and iron (which are also formed in the burners) need for their decomposition. It is claimed, however, that the zinc in excess of, say, 5 per cent. does not lock up any sulphur in the cinder. Some oxide of zinc is liable to be carried over into the flue, where it is deposited. The mining company supplies the ore broken to size and screened ready for charging into the burners. The ore is shipped over the Grand Trunk railway to Portland, a distance of 102 miles, and from there sent via the Eastern railroad to Boston (108 miles), or put on board vessels for New York and points south. The mine is owned by the Milan Mining Company of Boston.

Vermont.—At the Ely mine large quantities of low-grade pyrites are mined, but owing to its low sulphur contents and the inaccessibility to markets, it has not thus far been used for acid making.

Massachusetts.—In the town of Rowe, Franklin county, is the Davis mine, at which work was commenced in June, 1882. The vein varies between 12 and 22 feet in thickness, and has a dip of about 19°. The foot wall is a micaceous schist, and the hanging wall a chloritic slate. Two shafts, 350 feet apart, have been sunk on the dip of the vein. Shaft No. 1 has been carried to a depth of 300 feet and No. 2 to a depth of 130 feet, and hoisting appliances are in working order for raising 7,000 tons per month. Three drifts have been driven, aggregating 800 feet in length, and a considerable quantity of ore has been mined. The vein material is almost pure iron pyrites, with a slight admixture of copper pyrites and quartz. The iron pyrites is distinctly crystalline, the crystals being about one-tenth of an inch across. The proportions of the principal constituents of the ore are about as follows:

	Per cent.
Sulphur	48.0
Iron	44.0
Copper	1.6
Zinc, lead, etc	1.5
Silica	3.7
Arsenic	(?)
	98.8

The "smalls" ore is of remarkable purity, contains upwards of 48 per cent. sulphur, and is admirably suited for use in shelf burners or in Spence's mechanical furnace, in either of which it is readily burnt down to 3 per cent. sulphur. The smalls are all screened before being shipped from the mine, so that there are no pieces larger than $\frac{3}{16}$-inch size. A large quantity of Davis ore, both lump and smalls, has been burned during the past thirty months, and it is in favor with some manufacturers, who find it free from arsenic. This, while of no great moment so far as the quality of the greater portion of the acid made is concerned, may yet be an important matter as regards the wear and tear on chamber lead. The Davis ore is put on rail at Charlemont station, on the railroad belonging to the State of Massachusetts. Charlemont is 128 miles from Boston, 42 miles from Troy, and 104 miles from New Haven, which is the shipping port for New York and points south. From New Haven to Philadelphia, New York, etc., the ore is shipped aboard coal vessels, which are glad to get it as a return cargo at moderate rates.

New York.—There are mines in Saint Lawrence county, near De Kalb. The ore contains 38 to 40 per cent. sulphur and 2.75 per cent. copper. Some of it is said to contain considerable silver. The ore is shipped to Canada and to Detroit.

Virginia.—In Virginia are extensive supplies of rich pyrites that have taken a good place in the market. Several mines have been opened out in Louisa county, and a good deal of work has been done. The pyrites is overlaid with hematite iron ore, which has been worked, by an open cut, for iron making since 1834. The hematite has doubtless resulted from oxidation of the bisulphide. After passing through about 60 feet of "iron hat" the bed of pyrites is reached. Down to the 100-foot level it is generally decomposed and granular, falling readily to pieces, and it is permeated by water so heavily charged with salts of iron and copper as to destroy iron pipes or tools in a few weeks. Neither the foot nor hanging walls yield other than pure water. The deposits, which are 10 to 65 feet wide, lie wholly in the primary rocks, here consisting of gneiss and crystalline schists (micaceous, chloritic, and argillaceous) within a boundary inclosing, say, 3 miles in width by 10 miles in length, their general direction being northeast and southwest. The following analysis of Virginia ore is by Dr. Volcker, of London:

	Per cent.
Sulphur	48.02
Iron	42.01
Peroxide of iron	1.93
Sulphuric acid	.44
Silica	7.60
Copper	None.
Arsenic	None.
	100.00

Some chemists have detected the presence of arsenic, but there can be no doubt that if present the amount is altogether insignificant. Other analyses show 46 to 50 per cent. sulphur. Latterly the percentage of copper has increased to a gratifying extent, and in this way the value of the ore has been greatly changed. Three mines have been worked in Louisa county, belonging to the Arminius Copper Mines Company, the Sulphur Mines Company of Virginia, and Messrs. Charles Lenning and Boyd Smith, respectively. At the Arminius mine two shafts have been sunk, over 500 feet of drifts driven, and stopes capable of a daily output of several hundred tons are being worked. A Becket & McDowell hoist of the necessary capacity has been put in, and all the appurtenances required for doing a very large amount of work. A private tramway, 2 miles long, connects with the Chesapeake and Ohio railroad at Tolersville station. Tolersville is 56 miles from Richmond and 133 miles from

Newport News, either of which ports offers unexcelled facilities for shipping north or south. The mines of the Sulphur Mines Company of Virginia are 2 miles northeast of the Arminius mines. It is claimed that at these mines there are developments to the extent of a million tons of ore in sight, and the company proposes to build a railway connecting with Tolersville station at an early date. The Arminius and Sulphur Mines companies combined early in 1883.

Georgia.—The pyrites raised at two mines in this State has been used for the manufacture of sulphuric acid. The mine of the Tallapoosa Copper Reduction Company is in Haralson county, and that of the Paulding County Mining Company is in Paulding county. The mine belonging to the latter company is on the East Tennessee, Virginia and Georgia railroad, 30 miles northwest of Atlanta. The vein is a well-defined and regular one varying from 5 to 8 feet in width. The shaft has been sunk vertically, to a depth of 35 feet, to the vein, the dip of which (30°) it then follows. Some of the ore contains as much as 11 per cent. copper, but the average is very much lower. The Georgia ores are somewhat irregular in quality and the supply is intermittent, so much so that there is a probability of the chemical company at Atlanta which has been burning these ores abandoning them in favor of brimstone. They contain about

	Per cent.
Sulphur	40.00
Copper	2.75
Silica	8.00

Some ore from the Paulding County mine has been sent by rail to works in Tennessee.

Deposits not now worked.—There is scarcely a State in the Union in which pyrites does not occur to a considerable extent. At the present time all sulphuric-acid makers can be cheaply supplied from the mines already opened. As new acid-making centers spring up, doubtless many of the existing deposits not now worked will be drawn upon. Probably as the demand for sulphuric acid in the far West increases the extensive supplies of auriferous pyrites there worked will be utilized in its manufacture, unless the brimstone mines of Utah and Nevada are able to mine the ore and extract the sulphur at very low rates. For particulars in regard to the occurrence of pyrites in the different States reference may be made to the list published in the "Mineral Resources of the United States, 1882," beginning on page 667.

The deposits in South Carolina, though not developed, seem to offer strong inducements to capitalists considering the near proximity of Charleston and Baltimore. The ore mined about fifteen years ago at Anthony's Nose on the Hudson river, New York, was not pyrites but pyrrhotite, quite unsuitable for acid-making, and only indifferent success attended its use. Several thousand tons of it were used by different works in the vicinity of New York at a time when brimstone was selling at fabulous prices, but when the latter fell the manufacturers who had been using the ore were glad to return to the use of the brimstone, and would have done so even if they had not been compelled to by changes brought about through the mines having changed hands.

FOREIGN DEPOSITS.

Canada.—The ore from the Canadian deposits was the first to be used in this country for making sulphuric acid. It is now almost twenty years since the company at the head of which was the late General Adams opened out several properties in the province of Quebec, the ore from which was burnt at Malden, Massachusetts, Bridgeport, Connecticut, and at several works in the neighborhood of New York City. The mines subsequently came into the hands of a Scotch corporation, which retained all the ore for treatment (for copper) at the mines, and thus those manufacturers who had been using the ore were compelled to again resort to brimstone. The Canadian mines now furnishing pyrites for acid-making are the Albert mine, belonging to Messrs. G. H. Nichols & Co., of New York, and the Crown mine, belonging to the Orford Copper and Sulphur Company. The Crown mine is situated at Capelton, 8 miles from Sherbrooke and about 30 miles north of Newport, Vermont. The beds occur conformably with the stratification, forming in places large chimneys of ore sometimes 40 feet wide. These chimneys increase and diminish in width, thus forming lenticular pockets. The contractions occur both in the line of the strike and of the dip. With these chimneys exist horses which run down with them from the surface. One chimney may be chiefly iron pyrites, while the next may be principally copper pyrites. So regular are these formations that the foremen when opening up levels in new ground are able to tell what class of ore they are about to find. The country rock is a chloritic slate interspersed with a number of quartz veins which presumably are auriferous, as gold can be found in almost all the streams flowing from the hills. The ore is delivered through a tunnel 1,000 feet long over a short tramway to the spalling shed, thence over a gravity road to the Passumpsic railway, where it is dumped directly into cars. The cost of handling and delivering on the cars (exclusive of spalling) is said to be not over five cents per ton. The ore is quite compact and forms very few smalls in breaking. It burns well in the kilns, in which the charge may be 25 per cent. larger than with Spanish 48 per cent. ore. Its composition is about as follows:

	Per cent.
Sulphur	40
Iron	35
Copper	4
Silica	20
Arsenic	traces.
Silver	(*a*)

a Four ounces per ton.

The ore is shipped over the Passumpsic and connecting railroads to New Haven (330 miles), where it is put on board vessels for New York, in the vicinity of which city it is being used at the rate of about 1,300 tons per month. The cinders have been smelted at the works of the Orford Company, at Bergenport, New Jersey. Latterly considerable quantities have been treated by the wet process for both copper and silver, the relatively large proportion of the latter metal being a set-off to the comparatively low value of the residual purple iron ore, owing to the large percentage of silica.

The ore from the Albert mine contains less sulphur and more copper than that of the Crown. It is used at the works of the mine owners at Laurel Hill, Long Island. The cinders are afterwards smelted at the same works.

Spain and Portugal.—The most important foreign deposits are those of Spain and Portugal, the ore from which has been so successfully used in Europe for many years past. These deposits were worked for copper by the Phœnicians and Romans, but their recent development dates only about twenty-five years back. The metaliferous zone extends in an approximately east-and-west direction from El Castillo de las Guardas, north of the town of Seville in Spain, through the Spanish provinces of Seville and Huelva, and through Portugal to the Atlantic ocean. The beds have been opened at the eastern portion of the zone; that is, in western Spain and eastern Portugal. The zone is 10 to 15 miles wide and 90 miles long. The principal mines, reckoning from east to west, are the Rio Tinto, Poderosa, Buitron, and Tharsis in Spain, and San Domingo in Portugal. The province of Huelva, in which are the Rio Tinto and Tharsis mines, is composed of carbonaceous or culm schists and graywackes, plicated by the upheaval of granitic rock forming the Sierra Morena range, which runs parallel with the metalliferous zone. A later period was marked by the appearance of quartz-porphyry, while the deposits themselves are attributed to the Permian period by M. Cumenge, a leading French engineer, who believes them to be the equivalent of the carbonaceous schists of Mansfeld, the sandstones impregnated with copper ores of the Corrèze, of the Rhine, of the Saar, and of the Ural mountains. Since the formation of the pyrites deposits, movements have taken place which have caused fissures in the beds, and the upper portions of the deposits have, under atmospheric action, been converted into oxide of iron, forming an iron hat from 30 to 150 feet thick. In the southeastern part of the zone the schists have been covered by a horizontal layer of from 10 to 13 feet of rock which is mined as an iron ore. There are also eruptive rocks of a more recent date. The pyrites deposits are closely related to the porphyries, and are found at the contact of these and the sedimentary rocks or in the latter. The Rio Tinto Company has two principal seams of ore, the north vein and the south vein, 3,500 and 2,500 feet long respectively. The latter is the one from which most of the ore has thus far been taken. It is from 300 to 400 feet wide, and until recently has been worked only by an open cut. In this way upwards of 5,000,000 tons have been taken out, consisting of compact iron pyrites with spots of copper pyrites and black sulphide. At the western part of the south vein there are now four hoisting shafts and three ventilating pits, the main shaft being equipped with plant capable of handling a daily output of 1,800 to 2,000 tons. The north vein has been comparatively little worked so far. It is much more extensive than the south vein, being at some points as much as 1,600 feet wide. According to reliable estimates there are now opened out in the two veins 134,000,000 tons of ore, and it would seem that even after that is taken out the further supplies will be almost inexhaustible.

In 1883, 1,099,973 tons of ore were mined, of which 313,291 tons were exported and the balance was treated for copper at the mine. The ore is sorted into six classes: 1. Export ore. 2. Rich copper ore containing 7 to 8 per cent. copper. This is smelted at the mine and the matte is shipped to Swansea. 3. Roasting ore, which is roasted in heaps for use with ores of the next class. 4. Ore for special treatment in heaps. This is mixed with roasted ore of class 3 and built into large heaps. Smaller heaps of the same mixture of ores are set fire to alongside the large heaps. The gas produced by combustion mixes with the steam generated from the heating of the moistened mass and permeates the whole heap of ore, amounting to some 4,000,000 tons. Continuous streams of water are poured on the top of the heap, which dissolves out the copper as sulphate. The copper liquor is run into large reservoirs built of masonry, where the copper is precipitated by scrap iron. 5. Smalls; these are now treated by Doetsch's process. The ore, mixed with one-half of one per cent. of common salt and a like quantity of persulphate of iron, is built up into large heaps, and a solution of perchloride of iron is run on it in a continuous stream. The solution run off at the foot of the heap contains chloride of copper and protochloride of iron. After precipitation of the copper with scrap iron the solution of protochloride of iron is run down a brick tower packed with firebrick, etc., and is perchloridized by an ascending current of chlorine generated in a furnace from a mixture of common salt and persulphate of iron. The solution may now be used over again. The smalls ore treated by this process contains about 2.6 per cent. copper; 50 per cent. of this is dissolved out in four months, and 80 per cent. in two years. The iron pyrites remains unacted upon, and the sulphur contents of the leached ore is not sensibly less than that of the original ore. The 6th class of ore contains considerable quantities of copper, lead, and silver.

The following are two recent analyses of Rio Tinto export ore (that which is used for acid making):

	M. Cumenge.	"German analysis" reported by Mr. Walter Weldon.
	Per cent.	*Per cent.*
Sulphur	47.76	49.5
Iron	43.99	43.0
Copper	3.69	3.0
Lead	.10	1.0
Zinc	.24	
Arsenic	.83	
Silica	1.99	
Silver	(*a*)	(*b*)
Gold	(*c*)	(*d*)

a 40 grams per metric ton.
c 26 grams per metric ton.
b 89.2 milligrams per metric ton.
d 180 milligrams per metric ton.

The export ore is shipped over a private track to Huelva (50 miles), where the company has ample wharf accommodation. The cost of delivering Rio Tinto ore in England is stated to be as follows:

	Per ton.
Mining	$0 80
Freight to Huelva	0 50
Ocean freight	3 50
Total	4 80

The Rio Tinto Company's capital stock is $15,795,000, and it has bonds to the amount of about $18,000,000. It paid a dividend of 14 per cent. in 1883.

The Tharsis Sulphur and Copper Company, whose mines are west of those of the Rio Tinto, though not operating on so large a scale as the latter company, yet has a very extensive property, and moreover has metal-extraction works at all the principal manufacturing centers in England and Scotland, where it treats its own cinders from the neighboring acid works for copper and silver. It mined 490,000 tons in 1883, of which 202,318 tons were exported. Tharsis ore is softer than most of the peninsula ores, and some of it has the disagreeable property of exploding more or less in the burners; this is not the rule however. The company has its own railroad to Huelva and its own wharves in that port. Its paid-up capital is $5,708,000 and it has a debenture debt of $625,600. It paid a dividend of 27½ per cent. for the year 1883.

The San Domingo mine, belonging to the Mason & Barry Company, limited, is in the southeastern part of Portugal. The ore from this mine is the best for acid-making of all the ores of the peninsula, but its use does not extend much of late. In 1883, 382,555 tons of ore were mined and 123,450 tons exported, as compared with 405,029 tons mined and 129,437 tons exported in 1882. The capital of the company is $899,890, and it paid a dividend of 12½ per cent. for 1883.

France.—In France there are mines at Chessy and Sain Bel, near Lyons, belonging to MM. Pechiney & Co., which supply all the pyrites used in the south of France. The composition of the ore is about as follows:

	Per cent.
Sulphur	46.40
Iron	39.00
Copper	1.50
Alumina	3.75
Silica	9.25
Arsenic	.10
	100.00

The ore from Chessy consists of loosely-aggregated crystals, which very readily separate on being struck by a hammer. It is very free-burning, and is said to be frequently burnt to as low as 1.5 per cent. sulphur.

Germany.—In Germany the Westphalian pyrites is the most important. The bed occurs along with heavy spar, and is traced for a length of 2¼ miles. Its thickness varies from 4½ to 18 feet. The ore is of a gray color, and is not crystalline. It burns without requiring much care, but the sulphur cannot be got down very low, owing to the amount of zinc present. The composition of Westphalian ore is about as follows:

	Per cent.
Sulphur	45.60
Iron	38.52
Lead	.64
Zinc	6.00
Lime	.11
Oxygen	.37
Arsenic	trace.
Insoluble matter	8.70
	99.94

Other deposits in Europe possess principally a historical interest.

DOMESTIC PRODUCTION.

The production of pyrites in the United States during the last three years is given approximately below:

Pyrites mined in the United States in 1882, 1883, *and* 1884.

Years.	Tons of 2,240 pounds.	Spot value.
1882	12,000	$72,000
1883	25,000	137,500
1884	35,000	175,000

The amount of capital invested in pyrites mining is probably about $200,000, and the number of men employed in 1884 was 175.

IMPORTS.

Imports of pyrites into the United States from 1880 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Canadian.					New-found-land.	Spanish.	Total.
	Tons of 2,240 pounds.	Copper (*a*).		Value.	Duty.	Tons of 2,240 pounds.	Tons of 2,240 pounds.	Tons of 2,240 pounds.
		Per cent	*Pounds.*					
1880	1, 958	....	1, 125, 296	$156, 834	$33, 758	....	....	....
1881	10, 812	4. 0	982, 899	102, 543	29, 786	....	1, 115	11, 927
1882	23, 980	3. 0	1, 591, 814	160, 473	47, 754	....	5, 838	29, 818
1883	25, 211	2. 5	1, 403, 900	134, 400	39, 879	....	*b*10, 600	35, 811
1884 (*c*)	26, 000	3. 7	2, 154, 800	....	....	2, 000	16, 250	44, 250

a Copper contents—these are "dry assays"—1.30 per cent. less than actual (wet) assays. The Spanish ore imported has contained an average of only 1.25 per cent. copper (wet assay). Newfoundland ore contained about 3 per cent. wet assay.

b "Spanish" pyrites includes 1,473 tons Portugese (Mason & Barry) in 1883. The balance is almost all Rio Tinto ore.

c All the figures for 1884 are estimated, as also is the quantity of Spanish ore for 1883. This has been rendered necessary by the practice of some of the custom houses not keeping pyrites separate from iron ores.

MANUFACTURING.

Works burning pyrites.—There are at present twenty-three establishments in the United States burning pyrites. They are located as follows:

	Number.
Boston and eastern district	5
New York district	9
Philadelphia district	2
Baltimore district (including South Carolina and Georgia)	3
Western district	4
Total	23

Two of the works use Canadian ore; four, Spanish ore only; two Spanish and domestic, and fifteen domestic ore only.

Nine of these establishments use grate burners only; nine, grate and shelf burners; two, shelf burners only, and three use the Spence mechanical furnace.

The acid made at ten of the works is used in the manufacture of fertilizers, at three for oil refining, and at ten for miscellaneous purposes.

Terms on which ore is purchased.—The ore is usually bought under guarantee that it shall contain not less than an agreed percentage of sulphur, and that there shall not be more than a certain proportion of smalls, say 7.5 per cent., through a ¼-inch mesh screen. Sometimes it is stipulated that the amount of zinc in the ore shall not exceed, say, 2 per cent., but this is not usual. The cinders are either given to the buyer or are removed at the expense of the seller. The price is either fixed at so much per ton of 2,240 pounds, delivered at the buyer's works or at the port of shipment; or else at so many cents per unit of sulphur per ton of 2,240 pounds. At 12½ cents per unit, for example, this would be:

	Per ton of 2,240 pounds.
For 50 per cent. ore	$6 25
For 48 per cent. ore	6 00
For 46 per cent. ore	5 75
For 40 per cent. ore	5 00

Sampling.—It is recommended that the sampling be done at the buyer's works at the time of discharging, one tub in every forty (2.5 per cent.) being dumped separately in the ore shed. This is afterwards broken to furnace size and quartered down to say 1,200 pounds. This is now broken to walnut-size, mixed by shoveling, and quartered down to say 300 pounds, which is then to be crushed to the size of peas, mixed, and quartered down to say 72 pounds. This 72 pounds is then to be pulverized, passed through an ⅛-inch mesh screen, then quartered down to say 9 or 10 pounds; and this last amount is to be pulverized, passed through an 18-mesh screen and bottled, one bottle being sealed in the presence of representatives of the buyer and seller, for reference to an umpire chemist in case of dispute. If the difference between the assay of the seller's chemist and that of the buyer's chemist does not exceed one-half of one per cent., settlement may be made on the mean of the two assays; but if the difference is greater than one-half of one per cent., then the sealed sample is sent to an umpire chemist for final assay.

Assaying.—The sulphur is determined by one of two methods. The first, and probably the more accurate method, is to oxidize the weighed sample of ore by addition of say 20 c. c. of hydrochloric acid and 40 c. c. of nitric acid. It is heated very gently until action ceases, evaporated to dryness at a temperature of about 120° Fahr., when say 20 c. c. of hydrochloric acid is added, and it is again evaporated to dryness. It is then redissolved in a little hydrochloric acid, say 20 c. c., diluted with hot water, filtered, and the sulphuric acid in the filtrate is determined by precipitation by a solution of barium chloride. When one gram of ore is taken, the weight of the $BaSO_4 \times 13.734 =$ the percentage of sulphur. It is generally best to work with only one-half gram of pyrites, which must have been brought to an impalpable powder in an agate mortar. Instead of weighing the barium sulphate a standard solution of barium chloride may be used (38.125 grams $BaCl_2\ 2H_2O$ per liter), and the sulphuric acid determined volumetrically. Each c. c. = 1 per cent., when using ½ gram of sample.

The other plan of assaying in common use is to fuse $\frac{1}{2}$ gram or 1 gram of the pyrites (very finely pulverized) with twelve times its weight of a mixture of carbonate of soda and nitrate of potash in equal proportions. The fusion mixture and the weighed quantity of sample are thoroughly mixed in a platinum crucible, the cover of the latter is put on, and the crucible and its contents are gradually heated over a lamp till the mixture fuses. A state of quiet fusion is maintained for several minutes, the crucible is cooled, and the contents are washed out with hot water. The solution is filtered, the filtrate is acidified with hydrochloric acid, and the sulphur determined as before.

Sometimes the moisture in the sample is determined and allowed for in the assay and in the weight of the cargo, but unless the ore is very wet this is unnecessary. For, suppose we buy 100 tons of ore containing 1 per cent. moisture and 48 per cent. sulphur in the moist state,

$$100 \text{ tons} \times \frac{48}{100} = 48 \text{ tons sulphur to be paid for.}$$

Now if we determine the percentage of sulphur in the dried sample, or calculate it from the assay of the damp ore and the percentage of moisture found, we would find it to be

$$48 \times \frac{100}{99} = 48\frac{48}{99} \text{ per cent.}$$

We would then have—

Tons moist ore delivered	100
Less 1 per cent. moisture	1
Tons dry ore	99

$$99 \times \frac{48\frac{48}{99}}{100} = 48 \text{ tons sulphur to be paid for as above.}$$

Statistics of pyrites consumption.—The following figures, though not absolutely accurate (reliable returns from some works not being available), will serve to convey an idea of the extent to which pyrites has been and is used:

Pyrites burned in the United States.

	1881.	1882.	1883.	1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
Boston and eastern district	....	2,500	7,500	14,500
New York district	7,000	23,900	29,500	39,000
Philadelphia district Baltimore and southern district (including South Carolina and Georgia)	....	2,500	7,000	9,500
Western district	....	....	1,000	5,500
Total	7,000	28,900	45,000	68,500

The capital invested in the United States in producing sulphuric acid from pyrites (including chambers, towers, etc., but excluding platinum stills) is over $1,000,000, and the men employed (including mechanics for repairs, laborers, etc.) number 250. The value of the acid produced yearly—reckoning 30,000 tons of 66° acid at $19 per ton and the balance 50° acid at $9 per ton—is equal to $1,400,000. The capacity of the present combined plants is 7,500 tons of pyrites per month.

Pyrites mined, imported, and consumed in the United States from 1881 *to* 1884 *inclusive.*

Years.	Mined.	Imported.	Total.	Consumed.	Stock, December 31, 1884.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1881	....	11, 927	11, 927	7, 000	....
1882	12, 000	29, 818	41, 818	28, 900	....
1883	25, 000	35, 811	60, 811	45, 000	....
1884	35, 000	44, 250	79, 250	68, 500	....
Total	72, 000	121, 806	193, 806	149, 400	44, 406

The stock of ore on hand on December 31, 1884, is thus distributed

	Long tons.
At works	19, 000
At mines (domestic)	25, 406
Total	44, 406

FOREIGN STATISTICS.

It is interesting to compare with the foregoing figures the extent of the pyrites trade in Europe.

In England there were imported and produced in 1883:

From—	Long tons.
Norway	1, 271
Portugal	121, 137
Spain	473, 343
England and other countries	25, 000
Total	620, 751

In France there are now consumed, according to a communication from Dr. Lunge:

From—	Metric tons.
Domestic mines	150, 000
Sweden and Norway	20, 000
Belgium and elsewhere	10, 000
Total	180, 000

In Germany 148,717 tons (of 1,000 kilos) of pyrites was produced in 1883, practically the whole of which was used at home.

In Belgium very little pyrites is now used, probably not exceeding 10,000 tons per annum.

It will be seen that the total quantity of pyrites used throughout the world for sulphuric-acid making is over 1,000,000 tons per year.

PROCESSES.

There are three kinds of furnaces for roasting pyrites in common use—grate burners for burning ore in pieces, shelf burners, and Spence's mechanical furnace for burning "smalls" ore.

Grate burners.—Grate burners are built of firebrick in two rows back to back, the fronts being incased in ¾-inch cast-iron plates. From 12 to 30 burners (or even more, although this is not recommended) are combined to work through one set of chambers in two rows of from 6 to 15 each. The center wall between the two rows of burners is 14 or 18 inches thick, and the side walls between burner and burner are 9 or 14 inches thick, preferably 14 inches. The front wall, which is protected on the outside by cast-iron plates, is 9 inches thick. The side and back walls are sometimes made to taper upwards, but this is not necessary. The inside dimensions of a good size of burner are 5 feet 3 inches from front to back and 4 feet 6 inches wide. Such a burner will take care of from 700 to 800 pounds of 48 per cent. ore every twenty-four hours. The grate is about 18 inches from the ground. It consists of three cast-iron bearing bars, running from side to side of the burner at the front, middle, and back, and having a number of journals cast in the upper edge for the grate bars to work in; and a number of grate bars 1¾ inches square, rounded at three places in their length where they rest in the journals on the bearing-bars. The grate bars are 3¾ inches apart from center to center. The front ends of the grate bars are closed in by a tight-fitting double door working on hinges, and below is another door, 10 by 15 inches, for removing cinders from below the grate. There is no brick wall across the front of the burner below the grate—only the ¾-inch plate, on which is hung the ashpit door. Two feet three inches above the grate bars comes the charging door, 9 by 12 inches. This is usually hung on hinges, and it is made airtight. A small hole, 1½ by 2½ inches, closed by a slide, in the center of the charging door, allows the inside of the burner to be seen without opening the charging door. At some works the distance from the grate to the charging door is more than 2 feet 3 inches and at some less, the extremes being 2 feet 6 inches and 18 inches. The former size is too deep except for low-grade ores and the latter is too shallow. Between the grate and the charging door are two small doors, 4½ by 6 inches, one on each side, for pokering when clinkers get down on the grate. These doors are very seldom required to be used. On a level with the top of the charging door the 4½-inch arch over the burner springs from side to side. A hole 7 inches square is left about the center of the arch for the exit of gas into the flue. The front and back (or center) walls are carried up 9 inches above the crop of the above arch, and then another arch 4½ inches thick is sprung over each row of burners forming two flues for the passage of burner gas to a Glover tower or to the chambers. Such a burner will burn any ore in the market for acid making. The cost of each burner need not exceed $230. They can be built of ordinary red brick up to a foot above the grate. In starting up new burners, after slow drying for fifty or sixty hours the burners are filled with pyrites cinders (carefully screening out all dust beforehand) up to the level of the charging door, and a wood and coke fire is started on top. When the top of the ore and the arch, etc., are at a good red heat the wood and coke are removed and a charge of pyrites is thrown in. When pyrites cinders are not available for starting the burners, broken brick, slag, or any such material may be used instead. Each burner is charged with 350 to 400 pounds of 48 per cent. ore or 400 to 500 pounds of 40 per cent. ore every day of twelve hours in regular working. Before charging, the workman opens the grate-bar door, puts a key on the end of every alternate bar, and gives it a half dozen twists, thereby causing a portion of the cinders to pass through between the bars into the ashpit, from which they are afterwards removed. He then puts a poker through the top layer of ore, so as to break up any clinker that may have formed, levels off with a rake, and throws in the fresh charge of ore. For a block of twenty-six burners (which is a convenient number to work in one set) two men will be required on each twelve-hour shift. They charge and attend to the burners, drop the cinders and remove them from the ashpit to the dump, and "cook" the niter in the niter oven at the end of the burners.

Breaking lump ore for the grate burners is done by means of a Blake crusher or by hand. For hard compact ores a mechanical crusher is best; but for softer ores, making large quantities of smalls in breaking, hand work is preferred. This is by no means a drawback to soft ores, as they can very often be as cheaply broken by hand as hard ores can be handled by aid of a crusher. Where no smalls burners are used, and generally in small works, breaking by hand is preferable; but with hard ores, in works having a capacity of 120 tons and upwards per week, a mechanical crusher should be used. The cost of breaking the ore, wheeling to burners a distance of, say, 150 feet, and weighing on the way, should not exceed 50 cents per ton either by hand or by machine.

Shelf burners.—These solve the problem which puzzled practical men for many years—how to burn smalls ore without the aid of extraneous heat. They have been in use for about eight years, and have fully established their claim to be considered an economical means of furnishing sulphurous-acid gas from pyrites. In this country, where there are large quantities of soft ore cheaply mined and requiring no preliminary preparation for the burners, they and the Spence furnace (to be next described) are likely to be put up in increasing numbers. The burner consists of a number of fireclay shelves—seven—placed one above the other in a firebrick chamber, and so arranged that the ore raked off one shelf falls on the one next below. Each shelf is 4 feet wide and 7 feet 6 inches long. Assuming the shelves all to contain ore, the contents of the lowest shelf are raked into the ashpit, then the contents of the second shelf are raked off on to the bottom one and spread on it. Now the contents of the third shelf are raked on to the second one and spread there, and so on up to the top. When the charge on the top shelf has been raked on to the shelf below a fresh charge is dropped in through a hopper in the roof. An error sometimes made in building shelf burners is putting the shelves too far apart, which makes it difficult to maintain sufficient heat in the burner. If the lower shelves are not more than 6 inches apart and the upper ones are about 8 inches apart, this difficulty will never arise; that is, with regular attention on the part of the workmen. One man on each shift attends four shelf burners and removes the cinders to the dump. Each burner takes three charges of 550 pounds of 48 per cent. ore every 24 hours. Some persons claim to reduce the sulphur in cinders from shelf burners to 1.5 per cent. If this is really done, it is, to say the least, unusual; 2.5 per cent. may be considered very good work, and 3.5 per cent. good. The cost of building a shelf burner is about $550.

Spence mechanical furnace.—This is at work in three factories and is giving good results. It is a modified shelf burner (or rather a double shelf burner), the shelves in each half being four in number and 3 feet 4 inches by 14 feet 6 inches long. Instead of moving the ore in the furnace by hand, however, steam power is used for that purpose. Cast-iron rakes in each of the four compartments of each half are connected by a stout iron rod passing through a bush with an iron frame traveling on a railroad track outside the furnace. Motion is transmitted to this movable frame and system of rakes from a 10-horse-power engine working intermittently. Attached to this main engine is a small auxiliary engine with a 2½-inch cylinder. This small engine works continuously, and gives motion to a small spur wheel, which it turns round once in five minutes. In the side of the spur wheel near the periphery is a pin, and every time this pin comes round it catches the end of a rod, opens the steam valve, and sets the main engine in motion. The feed and discharge are both automatic. Each furnace burns 45,000 pounds of 48 per cent. ore per week. The help required is three men each shift to four furnaces, exclusive of steam-raising. The coal consumed for steam is 2 tons per furnace per week. The cost of erecting two furnaces with engines (one for two furnaces) and everything complete is about $6,000. These furnaces do excellent work, give a very rich gas, and reduce the sulphur in cinder to a minimum.

Carter-Walker furnace.—This furnace was tried in the spring of 1884 for burning smalls ore. Its construction may be thus described: Two vertical series of four retorts each are arranged in a brick chamber over a fire grate. The products of combustion from the coal fire envelop the retorts but do not mix with the gas from the burning pyrites. The retorts are made of fireclay, and are 18 inches in diameter by 12 feet long; they rest on the brick walls at each end of the furnace. From the upper part of each retort there is a channel conveying the gas from the retorts into dust chambers placed on each side of the furnace, from whence the gas goes to the chambers. The individual retorts communicate with one another at alternate ends, so that the ore being charged into the upper retorts has to travel in a serpentine line in order to reach the last retort, out of which it falls into a barrow waiting to receive it. The ore is automatically fed into the upper retorts by a screw arrangement, and is kept stirred continuously and at the same time is moved to the outlet into the next retort below by means of steel arms radiating from a hollow shaft through which a stream of water flows to keep it cool. The cinders come out from the lowest retorts in a continuous stream. The success attained in working pyrites with this furnace was not at all encouraging, and it has been abandoned. It seems to be particularly adapted for roasting sulphuret gold and silver ores.

Pugging smalls ore.—This is a method of dealing with smalls which was at one time extensively practiced in Europe and is still where shelf burners are not used. The pan of a pug-mill (with pan 8 feet 6 inches diameter and cast-iron edge-runners 3 feet 6 inches in diameter) is half filled with water. The edge-runners are then set in motion and smalls thrown in with a shovel. When the mixture comes to the consistency of a soft mud it is run out by opening a slide in the side of the pan, and is lifted upon the top of the pyrites burners and spread in layers about 3 inches thick. In about 36 hours all the water is expelled and the mud is baked into hard cakes. These are then broken up into pieces 3 inches square and charged into grate burners with ore in pieces. Usually it is considered advisable that the "pugged dust" should not exceed 25 per cent. of the whole charge, but in some cases as much as 50 per cent. has been burnt with satisfactory results, and pugged dust has even been burnt in grate burners by itself.

The operation in the pug-mill occupies about an hour and a half to each batch of 2½ long tons. Four men will in nine hours do all the work connected with pugging 12 long tons of dust, including wheeling the ore from the dump to the mill, pugging, wheeling and lifting on to burners, breaking up the dried cakes, and wheeling and weighing off to the burners. The cost of labor for pugging is therefore about 55 cents per ton. To this must be added the cost of coal for steam (this will not exceed 2 per cent. on the ore) and wear and tear. This last item is somewhat large, as the acid sulphate formed in pugging causes pretty rapid destruction of all iron tools, etc., that it comes in contact with. Sometimes a little green vitriol is added in the pugging. This causes the smalls to cake more firmly.

Glover tower.—Though not an essential, this is a very useful adjunct to a pyrites-acid plant. Where it is not used the burners must be combined in sets of not more than 16, lead concentrating pans mounted thereon to boil up acid for the absorbing tower, and a long pipe interposed between the burners and chambers in order to cool the gas. When using the Glover tower the gas is thoroughly cooled before entering the chambers, and thus the heavy wear on the latter is avoided; the acid required for absorbing is concentrated in the cheapest possible way; half the steam required for the chambers is got without any expense for fuel; and the niter is recovered from the nitrous vitriol in the most perfect manner possible. A Glover tower moreover acts as a sort of regulator and tends to neutralize sudden or great changes in the draught, and less chamber space is required when it is used. The bottom of the tower should be at least 15 feet above the level of the floor of the burner house, and it would be better to have it even 20 feet above. It should be at least 25 feet from the burner shaft, unless where the full concentrating action of the tower is required, when it may be only 15 feet off. Where the burner pipe is lined with firebrick the tower may be 35 feet from the shaft, or even more. The saucer should be at least 35-pound lead, better 45-pound; and the lower portion of the sides should be 25 to 30-pound. The firebrick lining should be 2 feet 3 inches thick for the first 5 or 6 feet, then 6 feet of 18-inch work, then 14-inch and 9-inch. Too much care cannot be taken in selecting the firebrick for the lining, and the superintendent should in every case give this his personal attention. The bricks should be chosen from the hottest part of the kiln, should be very heavily fired, close and non-porous in structure, and of a brownish color; and should have a clear metallic ring when beaten together. The corners of the bricks at the corners of the towers should be chipped off, or else a specially molded brick with rounded corners should be used. The packing should be entirely of washed flintstones or quartz (such as that from South Paris, Maine); coke is on no account to be used. The packing must never be dumped promiscuously into the tower, but must be carefully laid by hand. Care should be taken to have the lowest rail (or girt) on the side in which the burner pipe enters at a sufficient distance above the latter; it is best made of angle iron. It is necessary to have a good joint between the burner pipe and the collar of the tower, or it will certainly leak in a very short time.

Absorbing tower.—For a given amount of sulphur from pyrites a larger tower space is required than from brimstone. For 20 burners the absorber should be 40 by 7½ by 7½ feet, or else 8 feet diameter and 45 feet high; and one for 26 burners should be 45 by 8½ by 8½ feet.

Treatment of cinders.—Thus far no extensive use has been made of non-cupriferous pyrites cinders. Quite recently, however, a French corporation, the Terre Noire Company, has succeeded in using them in the manufacture of steel. The cinders (the sulphur in which is reduced to 1.5 per cent. in shelf burners) are mixed with 15 per cent. of hydraulic lime, with which they are thoroughly incorporated in suitable mills. The mixture is converted into bricks by machinery, and these, after drying, are charged in to blast furnaces of moderate height. The pig iron produced does not give a good wrought iron, owing to the arsenic present depriving it of its welding properties; but good steel (for purposes where it is not required to be welded) is made from it. With American ores, which are usually non-arseniferous or practically so, it is possible that the result obtained might be more satisfactory. The sulphur is said to be counteracted by the lime, and there is no phosphorus.

Smelting cupriferous cinders.—If the cinders contain over 5 per cent. of copper, or if they contain a considerable quantity of silica, it is best to smelt them. This is best done in the water-jacket cupolas, which are now so largely used in the West. If the cinder does not contain sufficient silica to produce a fusible slag, sand or other siliceous material must be added. If a very siliceous copper ore can be had at a reasonable price, it is the best flux to use. The cost of smelting in water-jacket cupola furnaces per short ton is as follows:

Labor	$0.50
Coke	1.00
Coal for steam	.10
Repairs	.25
	1.85

Of course the weight of flux must be taken into account in calculating the cost of smelting the cinder. The 40 per cent. matte produced may be broken with cobbing hammers or otherwise, and roasted in heaps or stalls four or five times, and then smelted for coarse copper. Generally it will be preferred to sell the matte to copper smelters, who will charge about 3½ cents per pound of copper for smelting and refining. For refining coarse copper the charge is about 1¼ cents per pound. One and three-tenths per cent. is deducted from the actual copper assay as allowance for loss in smelting. The cost of a complete smelting plant, capable of taking care of the cinders from 200 tons of pyrites per week, and producing a 40 per cent. matte therefrom, would be about $7,000. About 20,000 tons of pyrites cinder were smelted in 1883, and a like quantity in 1884.

Henderson wet process.—This process is peculiarly adapted for cinder containing from 2 to 5 per cent. copper, 1 ounce and upward of silver per ton, and only 2 to 7 per cent. silica. It is the process universally used in England for the treatment of Spanish cinders; upwards of 430,000 long tons are there treated annually. It consists in chloridizing the copper and silver by roasting with common salt; dissolving the chlorides out with hot water; precipitating the silver as iodide by means of a soluble iodide, and then the copper with metallic iron. There are five different stages in the process, namely:

1. Crushing the ore and mixing with salt.
2. Calcining or roasting.
3. Leaching.
4. Precipitating the silver from the argentiferous copper liquors.
5. Precipitating copper from the desilverized liquors.

Crushing.—The cinder is mixed with common salt in the proportion of 13 to 20 parts salt per 100 parts cinder, and is passed through a pair of Cornish rolls of say 36 inches in diameter and 18 inches face. The rolls are pressed together by means of powerful steel springs, and are so geared together that if any hard material accidentally gets between them they separate and allow the hard substance to pass without their getting out of gear. The crushed ore is passed through a revolving plate screen with slots one-tenth of an inch wide; the fine stuff passing through goes on to the calcining furnace, and the coarse is returned to the rolls. Such a mill will crush 6 to 7 tons per hour.

Calcining or roasting.—This is usually done in muffle furnaces having beds 30 to 35 feet long. The fire gases pass first over the muffle, then back under the bed, and return under the bed to the flue leading to the chimney. In another form of calcining furnace, introduced by the well known English metallurgist, Mr. Thomas Gibbs, the furnace bed is 70 feet long and is heated only from below. The inside of the muffle is connected with a condensing tower built of firebrick and packed with bricks and coke. Down this tower a stream of water is kept running for the purpose of condensing the acid gases evolved from the furnace mixture. The acid solution running off at the bottom of the tower is used for dissolving the oxide of copper out of the roasted ore, as we shall presently see. The charge of ore in a furnace with a 30 to 35-foot bed is about 6 tons. It is charged through holes in the roof and is in the furnace from 8 to 15 hours, according to circumstances. It is kept stirred from time to time, for which purpose there are doors along each side of the furnace about 5 feet apart. The inside width of the furnace is about 12 feet. When, judging from empirical signs (the cessation of sulphur flames and the greenish-gray color of the ore) the calcination seems to be completed, a little of the ore is taken from every part of the bed, mixed, and tested by washing with hot water, then with dilute hydrochloric acid, and lastly with nitro-hydrochloric acid. To this last solution an excess of ammonia is added and the ferric oxide is allowed to settle; the clear solution should have only a faint blue color. The object in working the calcining furnace is to oxidize all the sulphur and chloridize all the copper (or rather to render all the copper soluble with the least possible expenditure of acid in leaching) and silver. In cinder from the pyrites burner the copper exists somewhat as follows:

	Per cent.	
Soluble in water—copper as sulphate	40	
Soluble in dilute acid—copper as oxide	10	
		50
Soluble in nitro-hydrochloric acid—copper as sulphide		50
		100

In the calcined ore the copper exists as follows:

	Per cent.		
Soluble in water—copper as protochloride	70		
copper as subchloride	7		
		77	
Soluble in dilute acid—copper as oxide		20	
			97
Soluble in nitro-hydrochloric acid—copper as sulphide			3
			100

The heat of the furnace must not be allowed to exceed a dull red, for if it does a larger proportion of the protochloride will be decomposed and the subchloride formed therefrom, and as the subchloride is only soluble in a strong solution of the protochloride or of hydrochloric acid the inevitable result is faulty leaching and a good deal of bother from the crystallizing of the subchloride out of the liquors in the shoots, etc.

Leaching.—The red-hot ore from the calcining furnace is allowed to lie some time to cool, and is then taken while still quite hot to the leaching tanks. These are built of wood, and are about 10 feet square and 5½ feet deep. Each tank holds 20 tons of calcined ore, which rests on a false bottom on which a rough sort of filter is formed of screened furnace ashes. The ore is first washed with weak liquors from a previous operation, then with the acid solution from the condensing tower, and finally with hot water. Only the first (strong) liquors are run to the Claudet tanks; the weak liquors are used as first washings for another tank of ore. The residual ore is now thrown out of the leaching tanks and after draining is ready for shipping as purple iron ore.

Precipitating the silver.—The method employed for recovering the silver from the argentiferous copper liquors is the invention of Mr. F. Claudet. The silver contents of the liquor are first determined in the laboratory by precipitation with iodide of potassium and addition of chloride of lead, melting the precipitate with fusion mixture in a crucible, and cupelling the resulting button of lead. The liquors usually contain from 3 to 6 grains of silver per gallon, and from 0.2 to 0.7 pound of copper. The silver contents of the liquor having been ascertained, it is run, together with an excess of an iodide of zinc solution of known strength, into the "Claudet tanks," which are wooden vats, usually circular, of about 3,500 gallons capacity. The strength of the iodide of zinc solution varies considerably; it may be taken at say 500 grains silver per gallon—that is to say, of such strength that 1 gallon precipitates 500 grains silver. Its strength must be accurately determined when it is made up. An excess of about one-tenth of the iodide is added in order to insure precipitation of all the silver in the liquors. The reaction occurring on addition of iodide of zinc is

$$2\,\mathrm{AgCl} + \mathrm{ZnI_2} = 2\,\mathrm{AgI} + \mathrm{ZnCl_2}.$$

The liquor is allowed to settle for 48 hours, and is then run off into the copper-precipitating tank. The precipitated iodide of silver is allowed to accumulate in the Claudet tank for about a month, at the end of which time it is swept out into another vat, and after washing with dilute acid and water is digested with scrap zinc, when the following reaction occurs:

$$2\,\mathrm{AgI} + \mathrm{Zn} = \mathrm{ZnI_2} + 2\,\mathrm{Ag}.$$

The iodide of zinc is dissolved out and used over again for precipitating silver from fresh liquors. The silver residue, consisting of metallic silver mixed with a little gold and considerable sulphate of lead, etc., is sold to silver refiners, who pay about $1.05 per troy ounce for the silver it contains and usually a little for the gold likewise.

Precipitation of copper.—The desilverized copper liquors are precipitated with scrap iron in wooden vats. The liquor is kept at a temperature of from 150° to 170° Fahr. by injection of steam. The copper in the first liquor run on to the fresh iron is precipitated in three or four hours, each subsequent liquor taking longer to precipitate. When the iron is so enveloped in copper precipitate that about twenty-four hours are required to throw down the copper from a fresh liquor the tank is cleaned out and a fresh start is made. The test for the completion of precipitation of the copper from the liquors is made by dipping a bright knife blade in the liquor; if all the copper has been precipitated the blade remains bright, if not it becomes stained. When dried the precipitate contains 75 per cent. copper in the metallic state.

Refiners charge about 2 cents per pound of copper for refining the precipitate, and deduct the usual 1.3 per cent. from the wet assay. The iron required for precipitating is about 110 per cent. of the copper.

There are two wet-process plants in operation in the United States: one in Elizabeth, New Jersey, belonging to the New Jersey Extraction Works, limited, and one in Natrona, Pennsylvania, belonging to the Pennsylvania Salt Manufacturing Company. About 8,000 short tons of cinder were treated in 1883, and 10,000 tons in 1884.

Comparison of wet process with smelting.—The cost of the whole wet process is about $7 per short ton of cinder containing 4 per cent. copper. The cost of smelting a similar grade of cinder (assuming it to be siliceous enough to flux itself), and producing a 75 per cent. matte, will not exceed $2.25 per ton; but the amount of copper recovered by smelting will only be about 3.1 per cent. against 3.75 by the wet process, and the silver (amounting to say $1 or even more per ton of ore), which in the wet process is recovered, has little or no commercial value in the matte. The value of the purple iron ore must also be taken into account in comparing the two processes; in the present depressed state of the iron trade this is not very great. On the other hand, the cost of a wet-extraction plant is fully four times as great as a smelting plant, and requires four times as much ground space. But after all a comparison of the two processes is of little value, since a siliceous cinder cannot be advantageously treated by the wet process unless it contain say 3 ounces silver per ton, nor a highly basic cinder by the dry process unless a cheap flux is at hand.

Purple iron ore.—This is the residual ore from the wet process after extraction of the copper and silver. Its composition is about as follows:

	Per cent.
Peroxide of iron (64.4 per cent. metallic iron)	92.00
Copper	.15
Sulphur	.10
Metallic sulphates	2.75
Phosphorus	
Insoluble matter	5.00
	100.00

It is used as a "fix" for puddling furnaces and in admixture with other ore in pieces for making pig iron. It has been used in the direct process for making wrought iron and steel. For use in blast furnaces without admixture of other ores it has been made into a mortar with clay, then allowed to set, and afterwards broken up with picks and taken direct to the blast furnaces. The method of mixing it with hydraulic lime (in the manner spoken of under the head of treating non-cupriferous ores) seems worthy of attention. In England, where so much of this purple iron ore is produced, there is a sufficient demand for it at remunerative prices for mixing with other ores in blast furnaces for production of Bessemer pig and for "fix." Accessibility to iron-making centers is an important consideration in locating wet-extraction works.

Comparison of American and foreign pyrites.—Thus far no deposits have been found in America comparable in extent with those in Spain and Portugal, the mines of which practically control the whole pyrites trade of the Old World; but this is to some extent compensated by an even distribution of deposits of moderate extent in different parts of the country. So far as burning qualities and adaptability to sulphuric-acid making is concerned, American ores compare favorably with Spanish. It is true that in some domestic mines a good deal of smalls is produced, owing to the friable nature of the ore, but since the advent of shelf burners and the Spence mechanical furnace these can be burned quite as economically as lump ore, and in some cases even more so. The average sulphur contents of domestic ores is equal to that of Spanish, and they are all practically free from arsenic or nearly so, while Spanish ores contain from 0.25 to 1 per cent. and Canadian ores contain notable quantities. On the other hand, it cannot be said that any American ores possess *all* the elements for a great commercial success such as attends the treatment of Spanish ores. The requirements for this are:

1. Nearness of the mines to manufacturing centers and cheapness of transportation thereto. Domestic mines compare favorably in this respect.

2. High sulphur contents—48 per cent. with highly basic ore (say 3 to 4 per cent. silica), or 40 per cent. with a siliceous ore (20 per cent. silica). American ores are quite up to this requirement.

3. Copper and silver in suitable quantity. With a highly basic ore, copper should be 3 to 4 per cent. and silver 1 ounce or more per ton. With siliceous ore the copper contents should range from 3 to 5 per cent. At the present time the silver in a siliceous pyrites ore cannot be said to have a steady commercial value, but doubtless will have shortly when the extraction of silver from copper mattes shall have become an established success, as it bids fair soon to be.

4. The silica contents should be either 3 to 5 per cent., or else about 20 per cent.

5. The ore should be comparatively free from zinc, lead, lime, etc., and should contain only traces of arsenic.

Competition of foreign and domestic ores.—At the outset it may be said that the importation of Canadian ores is likely to continue unless very improbable changes are made in our tariff laws; for while there is no doubt that the cost of mining and delivering in the New York district is fully as much as the sulphur value of the ores, yet they contain enough copper to make the treatment of the cinder quite remunerative, and it is on this that the miners depend for their profits. In regard to Spanish ore, the present position of affairs is rather more obscured, for while one of the Spanish companies is delivering ore to three works, under contract, it has shown a total disinclination to accept any further business, and evidently has no present desire to cultivate the American trade. Another of the large Spanish companies has recently declared its inability to furnish any lump ore for this market, and quotes smalls at such a price as give it no chance of competing with domestic ores. The third great Spanish company is not, I think, in position and does not desire to ship any large quantity of ore to this country, for the present at least. None of the companies seem to show any inclination to sell ores just now for less than 12 shillings (say $3) per ton of 2,240 pounds free on board at Huelva or Pomaron. Adding to this $2.75 freight and 75 cents duty, we have as the price delivered on steamer in Boston or New York $6.50 exclusive of insurance and interest. It is not unlikely that a large quantity of smalls, the copper of which has been extracted by Doetsch's process, will seek a market here within a year or two, when the heaps now being worked at the mines have become exhausted of copper. The probable effect of the introduction of sulphur recovery and ammonia-soda processes in Europe will be discussed further on.

Comparison of pyrites and brimstone.—There can be no doubt that acid can be made from pyrites much cheaper than from brimstone. The points that require to be kept in view in making a comparison of the two processes are: The cost of burners for pyrites is twice as much as for brimstone. Where a Glover tower is added to the plant no more chamber space is required for burning pyrites than for brimstone; 20 cubic feet per pound of sulphur burnt off is ample. Many works using pyrites have too many hands. In a works having 24 to 30 grate burners only eight men are really needed in all, two on day shift breaking ore and wheeling to burners, two burner men on each shift who also pot niter and wheel away cinder, one man on each-shift attending steam boiler, pumping acid, and attending chambers. This is equal to say 35 cents per ton of 50° acid. The cost of labor with brimstone where niter recovery is practiced is about $1.25 per short ton, or 27 cents per ton of 50° acid. In well conducted works, with Glover and Gay-Lussac towers, there is no difference in niter consumption with pyrites or brimstone. As to yield of acid, with pyrites 280 to 290 parts sulphuric acid (66° Baumé) are obtained per 100 of sulphur contained in the ore.

The coal consumption is generally less with pyrites than with brimstone. The wear and tear is between 20 and 30 per cent. greater with pyrites than with brimstone.

PRESENT STATE OF THE PYRITES INDUSTRY.

From the miner's standpoint the present condition of the industry is highly satisfactory, though selling prices of ore are very low. The mines are now in better shape than they have ever been, and the business of mining and shipping has been thoroughly systematized and costs reduced to a minimum. They are now in position to meet any demand for ore likely to occur, and are anxiously waiting for a still more extended use of pyrites. From a manufacturing point of view the only unsatisfactory thing is the low price of acid; and while this has doubtless been caused, in great part at least, by the cheapening of production consequent on the adoption of pyrites, it is pleasing to know that the reduction in price has been no more than commensurate with the cheapening of cost. Another point here worthy of notice is the reduction in the price of brimstone which has taken place since the introduction of pyrites. In the early part of 1882 best unmixed seconds was worth about $31 per ton, at the close of 1884 it is selling at about $23. As regards the probability of pyrites ever entirely taking the place of brimstone it should be noted that the prejudice at one time existing against pyrites acid is gradually giving way. Pyrites acid is equally as good for most purposes as brimstone acid; the only drawbracks to it are the occasional presence of iron and arsenic in it. With domestic ores the amount of arsenic is usually infinitesimal, and will generally only debar the use of the acid for substances used in the preparation of pure chemicals, etc. When using arsenical pyrites the arsenic is almost all deposited in the Glover tower and first chamber, the last chamber acid containing very little, as the following tests of acid made from Spanish ore will show:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
As_2O_3 in acid from 1st chamber	0.286	0.224
As_2O_3 in acid from 2d chamber	0.060	0.031
As_2O_3 in acid from 3d chamber	0.031	0.010

But even supposing that all our pyrites were slightly arsenical, that would not prevent its almost universal adoption. The principal uses of sulphuric acid in this country are for oil-refining and fertilizer-making, and for these two uses sulphuric acid containing a little arsenic is equally as good as the purest brimstone acid. The following brief abstract will show for what purposes the acid made throughout the country is used:

	Per cent.	
For oil-refining	45	
For fertilizer-making	45	
		90
For other uses		10
		100

It is interesting to compare with the above the following statement showing the purposes for which sulphuric acid made in England is used:

	Per cent.	
In making sulphate of soda for the Le Blanc soda process	49	
In making sulphate of soda for glass manufacture, etc	7	
In making fertilizers	22	
		78
For all other purposes		22
		100

In regard to acid plants there are in this country as fine works as can be found anywhere; those of the Bergenport Chemical Company at Bergenport, New Jersey, and of the Bradley Fertilizer Company at North Weymouth, Massachusetts, with their splendid arrangements of smalls burners, Glover and Gay-Lussac towers, will compare favorably with the best European works.

Recovery of sulphur from "tank waste" in Europe.—This is a thing which may exercise an important influence on our pyrites market. Tank waste consists essentially of sulphide of calcium. It is produced in the "ball furnace" in alkali works by fluxing a mixture of sulphate of soda, limestone, and coal. The change which takes place may be thus represented:

$$Na_2SO_4+CaCo_3+C=Na_2CO_3+CaS+CO_2.$$

The carbonate of soda is dissolved out with hot water and the sulphide of calcium (tank waste) remains. This has mostly been dumped on vacant land reserved for the purpose or else sent out to sea and dumped there. A small quantity has been treated for sulphur for several years past, 2,000 or 3,000 tons (or even more) of which have been recovered annually. A little of this recovered sulphur has found its way into the New York market, but as it contains arsenic it has not been favorably received.

Let us consider the probable effect of the universal adoption of this process in England alone. There are used annually in that country in the soda manufacture about 350,000 tons of pyrites, containing 168,000 tons of sulphur. The tank waste produced contains 90 per cent. of this, or 151,200 tons. Assuming it possible to recover 85 per cent. of this, the quantity of sulphur recovered annually would be 128,500 tons, equal to about 285,000 tons of pyrites. The probable effect of a diminution in the consumption of pyrites in England to the extent of 285,000 tons a year need not be commented on here.

The important question now comes in: At what cost could a ton of sulphur be produced by this process? Mr. Walter Weldon in January, 1883, said that it could ultimately be recovered for about $10 (£2) per ton. To compete with this, pyrites would have to come down to $4 per ton or even less, or say 8 to 8½ cents per unit. The effect already produced by the agitation of the sulphur-recovery process (supplemented by the threatening attitude of the ammonia-soda process toward the old Le Blanc process) has been the reduction of the price of pyrites in England to 9 cents (4½ *d.*) per unit, or $4.36 per ton of 2,240 pounds. Since this reduction took place the sulphur-recovery agitation has subsided, but will undoubtedly recommence at the first sign of any increase in the price of pyrites.

The ammonia-soda process.—The extending use of this process in Europe and in the United States is a matter of great interest not only to European soda makers but also to American chemical and fertilizer manufacturers, oil refiners, etc. In the old Le Blanc soda process—by which up till about ten years ago all the soda in the world (with trifling exception) was made—common salt is first converted into sulphate of soda by the action of sulphuric acid, and the sulphate of soda is then converted into carbonate in the manner described in speaking of the recovery of sulphur from tank waste. For the production of the 545,000 tons of Le Blanc soda (stated as Na_2CO_3) annually made throughout the world about 874,000 tons of sulphate of soda are required; and the sulphuric acid used in making that amount of sulphate necessitates the burning of 496,000 tons of pyrites.

In the new ammonia-soda process no sulphuric acid is required, soda being produced by the action of ammonia (constantly regenerated) and carbonic acid gas on a strong solution of common salt. Soda can be made by this new process for 25 per cent. less than by the old, and at the present time one-fourth of all the soda being annually made is produced by the new process.

The only thing which has prevented (and still prevents) the universal adoption of the new process is the fact that in it the chlorine of the common salt is all lost (as useless chloride of calcium), whereas by the old process it is liberated as hydrochloric acid gas in the decomposition of common salt, and after condensation this hydrochloric acid is used for generating free chlorine for the manufacture of bleaching powder. By combining to raise the price of this commodity Le Blanc soda makers have been able to compensate themselves for the loss sustained in selling soda below the cost of production.

Many ingenious inventors are now at work trying to solve the problem how to obtain free chlorine (for bleaching powder) economically by the new process. If these efforts prove successful the days of the old Le Blanc process are numbered, and the 496,000 tons of pyrites now used annually in the decomposition of common salt will have to be diverted into other channels.

But whether the efforts to obtain free chlorine—in other words, bleaching powder—by the new process prove immediately successful or not, its further advance cannot be delayed for this reason: 1 ton of bleaching powder is made from the hydrochloric acid liberated in the decomposition of 2½ tons of common salt. Now in England there are made annually 140,000 tons of bleaching powder; 140,000 × 2.5 = 400,000 tons salt required annually for the production of bleaching powder. Deducting 400,000 from 560,000 (the number of tons of common salt used annually in making Le Blanc soda) leaves 160,000 tons common salt, equal to 110,000 tons soda (stated as Na_2Co_3). This represents the probable immediate increase in the annual amount of ammonia soda made; and the output of Le Blanc soda will probably immediately decrease to a like extent. This decrease in the output of Le Blanc soda will bring about a reduction in the quantity of pyrites consumed in England to the extent of about 100,000 tons, and the reduction on the continent will probably be an additional 30,000 tons of pyrites.

To sum up these different phases of the European soda and pyrites trades:

1. The possibility of the economical recovery of sulphur from tank waste will in all probability prevent the price of pyrites in Europe rising above 9 cents per unit of sulphur, even if we leave out of account for the moment the effect of an inevitable decrease in the amount of pyrites required by Le Blanc soda manufacturers.

2. There will be a decrease during the next two or three years in the quantity of Le Blanc soda made in Europe annually of 140,000 tons and of pyrites burned of 130,000 tons.

3. If the attempts to obtain free chlorine in the ammonia-soda process prove immediately successful, the old Le Blanc soda process will probably be extinct in a few years, and the 496,000 tons per year of pyrites now used for it will have to be utilized in some other way. The extinction of the Le Blanc process would also be brought about by the discovery of a cheaper bleaching agent than chlorine.

Effect of reduced consumption of pyrites in Europe on the American market.—Let us now briefly consider the probable effect of a reduced consumption of pyrites in Europe on our domestic market. In the first place it will probably result in the Spanish companies endeavoring to compensate for the loss of European business by shipping at first large quantities of non-cupriferous ore to this country. When the volume of business here becomes large enough they will probably make extensive arrangements for treating the cinders and begin to ship cupriferous ore here, unless indeed they can make more profit by treating the ore for copper at the mines in Spain. This last supposition seems extremely improbable. The cost of treating a 3 per cent. ore for copper at the mines is probably in no case less than \$2 per ton. If the same ore were shipped to this country the debits and credits would stand about as follows:

DEBITS.		CREDITS.	
Freight to Huelva	\$0.50	Sulphur (say)	\$5.75
Duty 75 cents per ton, plus 10 per cent. of 2½ cents per pound on 1 per cent. copper	0.80	Purple ore (\$3 per ton)	2.10
Ocean freight, etc	2.75	Silver	0.75
Treatment of cinder	4.90		8.60
Balance (in favor of shipping to this country)	1.65	Add cost of treatment at mine	2.00
	10.60		10.60

The cement copper is supposed to be shipped to England in either case.

It may be that these apprehensions of extensive foreign competition with domestic ores are unwarranted, but at all events sufficient has been said to justify the belief that the price of pyrites in this country as well as in Europe can never be much if any higher than at present. Some persons even believe that in the near future pyrites mines will supply the ore to acid makers for nothing, the only condition being that the cinders shall be sent to extraction works belonging to the sellers of the ore; but there is not much ground for such a belief, as it will always pay better to treat the ores for copper at the mine (where labor is usually much cheaper than in manufacturing centers) rather than in the neighborhood of acid works, unless a fair price can be had for the sulphur contents.

MICA.

By F. W. Clarke.[a]

Although the term "mica" covers a number of mineral species all similar in their scaly structure and general chemical composition, only one of these species has any commercial value or is popularly recognized under the generic name. This species, muscovite, is one of the commonest minerals, and occurs in greater or less quantity in a variety of rocks. Usually, however, it is disseminated in minute scales of no practical value; its occurrence in sheets or plates large enough for economic working being quite limited. Even when it is found of sufficient size and in sufficient abundance, it is apt to be defective in structure or so stained and spotted with impurities as to be worthless. In order to be advantageously marketed mica should yield trimmed plates not less than 3 inches square; and these should be tough, clear, even in texture, and capable of being smoothly split into exceedingly thin layers. Even in localities which yield mica abundantly only a small portion of the mineral taken out is available for the ordinary uses. Accordingly we find around every mica mine an accumulation of waste scraps and clippings far exceeding in quantity the mineral which has been trimmed and marketed. The latter is chiefly used in the manufacture of stoves, lampshades, and lanterns; although some of the finest mica is employed for the dial plates of compasses. Various plans have been proposed for the utilization of the refuse. Finely ground, it is recommended as an absorbent for nitroglycerine in the preparation of high explosives; it is also used as a lubricant for machinery, as an ingredient of some glistening wall-papers, in the manufacture of "brocade" pigments, and as a substitute for asbestus in the production of fireproof roofings. None of these latter uses, however, can yet be regarded as having much economic importance.

Atlantic States.—Along the eastern slopes of the Appalachian system, in an almost continuous belt from Maine to Alabama, are scattered many workable deposits of mica. These occur in coarse granite veins, cutting through walls of mica-schist, and having in general a northeast and southwest direction. In other words, these veins are parallel to the main trend of the mountain system, and wherever they are found they possess a noteworthy uniformity of character. As a rule, the mica occurs in bunches or pockets, associated with large masses of quartz and

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[a] Special reports to this office by F. F. Chisolm and C. G. Yale, representing work done west of the Mississippi, have been freely used in the preparation of this chapter.

huge crystallizations of feldspar. Besides these commoner species, which pertain properly to granite, these veins are remarkable for their rarer mineral contents. Tourmaline and garnet almost invariably occur in them, beryl is nearly as certain to be found, various phosphates are frequently encountered, and such rare minerals as columbite, samarskite, autunite, etc., are often met with. In short, the rarer chemical elements, such as glucinum, columbium, tantalum, the cerium and yttrium groups, and uranium, are found most abundantly in these coarse veins of granite. Mineralogically, therefore, every mica mine is well worth studying and watching. Sometimes a mine which fails with regard to mica, yields enough merchantable quartz or feldspar to pay well for working.

Beginning with the New England States, we find mica mining carried on in numerous localities. In Maine, unsuccessful attempts have been made at Gilead and Albany, and promising deposits of mica are said to exist in the adjacent towns of Woodstock and Rumford. In Paris, at Mount Mica, from the same deposit which has yielded the famous gem tourmalines, a good deal of excellent mica has been taken out and sold. Southward, along the seacoast, the granite veins attain an enormous development; but here they are chiefly valuable for their feldspar. Some mica, however, has been produced along with quartz and feldspar at Edgecombe.

In New Hampshire, along a belt of country southwestward of the White mountains, mica mining is quite an old and well established industry. The "mica belt" first becomes conspicuous in the town of Rumney; and actual workings have been carried on in Orange, Groton, Grafton, Springfield, Alexandria, New Hampton, Wilmot, Marlborough, Acworth, and Alstead. Throughout this region the granite veins are most conspicuous objects, and often they may be seen from miles away cropping out along the barren hillsides. The most important mines are in Groton, Grafton, and Alstead, and large quantities of mica are annually taken out and sent to market. In Alstead, work has been carried on interruptedly for more than forty years, and the locality has yielded sheets of mica nearly 4 feet across. In Grafton, no less than six mines have been recently worked, and one of them, the old Ruggles mine on Isinglass hill, has been a recognized source of mica ever since the close of the last century. Throughout this time it has been in the hands of one family, and it is still worked on a large scale with steam drills and other modern appliances. In 1883 a single mass of mica weighing 512 pounds was taken out. Near by, on Alger hill, is another locality, which is remarkable for having yielded the largest crystals of beryl known in the world; one of them weighed over two tons. Still another recent mine is on Hoyt hill in Orange, and important work is progressing in Groton, about 5 miles south of the railroad station in Rumney. All these mines are either trenches or tunnels, no deep shafts having been sunk in this region.

Passing southward from New Hampshire, we find similar granite veins in Massachusetts and Connecticut; but in the latter State, notably in the towns of Glastonbury, Portland, Middletown, and Haddam, they are worked chiefly for the feldspar which they contain. In New Jersey a few attempts at mica mining have been made, and promising discoveries of mica have been reported in Pennsylvania, at South mountain and in Salisbury township.

As we leave the glaciated country of the north, the mica-bearing belt becomes less easy to recognize and to follow. Nevertheless, there has been quite recently a good deal of activity among mica miners in Maryland, especially in Howard and Montgomery counties. In this region a number of vertical shafts have been sunk into mica-bearing veins, passing through kaolinized rock of varying thickness before reaching the solid material. One group of mines is situated a few miles west of Laurel; and another mine, the Gilmore, is near Colesville, and only 12 miles north of Washington, District of Columbia. At the Gilmore mine there is a vertical shaft about 50 feet deep, and two horizontal tunnels; and a considerable quantity of good mica has been taken out. At present, however, but little work is being done in this field.

Southward from Maryland the mica belt extends across Virginia, and is recognizable at many points. Mica mining has been carried on in Amherst, Bedford, Hanover, and Amelia counties, although there is at present a slackening of activity in this region. At Amelia Court House the mica was associated with an extraordinary variety of rare minerals, notably with beryl, columbite, helvite, microlite, and monazite; but this locality is now abandoned, and the mine is full of water. A tier of counties along the southern boundary of the State, especially Grayson, Henry, Patrick, Carroll, etc., offers a promising field for exploration in search of mica.

In South Carolina, Georgia, and eastern Alabama, workable deposits of mica undoubtedly exist, although no substantial investigation of them has yet been made. In North Carolina, on the other hand, the mica industry is important and flourishing, and the Appalachian mica belt here attains its greatest development. Mica mines occur in Ashe, Mitchell, Yancey, McDowell, Cleveland, Alexander, Wilkes, Burke, Catawba, Buncombe, Haywood, Jackson, Macon, and other counties, and explorations for mica, more or less superficial, may be counted by hundreds. The greatest production of mica is in Yancey, Mitchell, and Macon counties, and the more important centers of the industry are Bakersville, Burnsville, and Franklin. Mica mining is carried on to some extent near Marion; and in the neighborhood of Jefferson, in Ashe county, there are many promising but undeveloped localities. The Ray mine, near Burnsville, is one of the most noteworthy of the mica mines, but the Iotla and Burningtown mines near Franklin, and the Fraly mine in Jackson county, also deserve mention. The Clarissa mine, once highly important, is now no longer worked. Some of these mines are notable for their deep shafts, and differ in this particular quite strikingly from the mica mines of New Hampshire. Here also, as in the North, the mica is notably associated with many rare minerals of great scientific interest; samarskite, for instance, has literally been found by the ton in some of the localities. Another interesting point in connection with the North Carolina mines is the fact that the best of them were discovered by evidences of prehistoric working. In 1868 attention was called to some supposed "old Spanish silver mines" near Bakersville. These were examined by Prof. W. C. Kerr, who found them to be ancient and very extensive workings for mica; and it is now certain that from them came much of the mineral which occurs in various ornamental forms in the mounds of Tennessee and the Ohio valley. The mines in Macon and Jackson counties exhibit similar traces of aboriginal working.

Quite recently a company has been organized to mine for mica near Republic, in the northern peninsula of Michigan; but, with this exception, the industry does not exist between the Appalachians and the Black Hills.

Black Hills.—In this region mica mining has of late years assumed great importance. The mines are mostly in Custer and Pennington counties, Dakota, in the granitic intrusions which form the rugged peaks in the center of the district. This granite is remarkable for the extreme coarseness of the crystallization, the constituent minerals being generally segregated into large masses. From this granite the aggregations of mica are quarried out, and with the mica, as in the East, are found extraordinary quantities of beryl, tantalite, columbite, spodumene, etc. One mass of columbite, reported by W. P. Blake, was estimated to weigh more than a ton. In almost all of the mica mines of this region tin is also found. Although numerous claims are held in the mica district only a few have been practically developed. The earliest explorations for mica were made in 1879, the McMacken or Black Hills mine being the first upon which much work was done. This mine has been so far the largest producer in the region, and from it some 45,000 pounds of mica have been shipped, bringing an average price of $3 per pound, or a total of $135,000. Only the summer season has been available for working. The New York mine produces mica ranging from 3 by 5 to 9 by 12 inches in size, and 2,500 pounds of such mica were sold by the original discoverers at an average price of $3.50 per pound. At present there are fourteen men employed in the mines, and the weekly output is 150 pounds of good mica. Only about 5 per cent. of the total mica extracted is of merchantable quality. The entire product of this mine up to date has been 5,700 pounds, which sold for $19,950. The Lost Bonanza mine yields a remarkably clear mica, and some sheets have been cut as large as 13 by 16 inches, the average, however, being only 4 by 5. Twenty-six thousand pounds of this mica have been sold in Chicago at an average price of $4.35 per pound, or $113,100 for the entire output. Seven men are employed, and the weekly yield in July, 1884, was 150 pounds. The Climax mine has been well opened, and produces an excellent mica, which brings an average price of $4.35 per pound. The product of the mine from March, 1883, to January 1, 1884, was 4,840 pounds, and from January 1 to July 1, 1884, 3,100 pounds; a total of 7,940 pounds, which was marketed in Chicago for $34,539. Seven men are employed, and the average weekly product in July, 1884, was 120 pounds of merchantable mica. There are several other mica mines in Custer county, and numerous prospects upon which some work has been done and from which smaller quantities of mica have been shipped. Among these, the Demund, Ola, Last Chance, Boss, Nellie, Sitting Bull, Rosa, Crescent, Denver, Hillside, Sioux City, Emma, Window Light, Eureka, Grand View, Gray Eagle, Revenue, Old Mike, and Spotted Tiger mines have been developed to some extent. In Pennington county some small shipments of mica have been made from the Emma, Peerless, Celia, Alice, and a few other mines, situated about three miles southwest from Harney. Mica mining in the Black Hills is, however, yet in its infancy; and there is every indication that many of the undeveloped claims are as good as those which have produced largely. The product for 1884 was fully double that of 1883. To recapitulate, the product of the mines in Custer county has been up to July 1, 1884:

Production of mica in Custer county, Dakota, to July 1, 1884.

Mines.	Pounds.	Value.
Black Hills	45,000	$135,000
New York	5,700	19,950
Lost Bonanza	26,000	113,100
Climax	7,940	34,539
All other mines (estimated)	40,000	140,000
Total	124,640	442,589

The production of the mines in the Black Hills in 1884 has been reported almost exactly, and was as follows:

Mines.	Pounds.
Climax	5,000
Lost Bonanza	3,000
White Spar	2,000
Eureka	500
New York	5,000
Last Chance	300
Warren	250
Keystone	800
Window Light	600
McMacken, or Black Hills	Closed
Millard	400
Nellie	300
Occidental	Closed
Total product in 1884	18,150
Value of product at $3.50 per pound	$63,525

Rocky mountains.—In Colorado mica has long been known to be widely disseminated and to occur in many places in bodies of workable size, but mining has until lately always proved the mica to be "plumose" and unfit for cutting into sheets. Many mines have been located, but the product has always proved worthless, until in the summer of 1884 the Denver Mica Company opened a mine near Turkey creek, about 35 miles from Denver. This mica is of fair quality, and quite a considerable quantity of it has been mined. It is slightly brown and the largest plates which have yet been cut are not more than 2¾ by 6 inches in size. Only an extremely small percentage of the gross weight is available for cutting into sheets. An effort is being made to put it upon the market, and at present four workmen are employed in trimming the sheets. Mica of good quality and in large plates has also been recently reported from the neighborhood of Fort Collins.

In Wyoming, mica has been found in workable quantities near Diamond Park and in the Wind River country, as well as at many points along the mountain ranges in Laramie county. It has recently been mined to some extent at Whalen cañon, 20 miles north of Fort Laramie, and some of the product has been shipped to the Eastern market.

In New Mexico mica occurs near Las Vegas, and reports of shipments have been published. At Petaca, the Cribbenville mica mines are being worked at present by sixteen men. Work was commenced at these mines July 2, 1884, and the amount of excavation at present is 13,160 cubic feet. The plates cut range from 2 by 2 inches to 5 by 8 inches in size. Some specimen plates have been cut 10 by 12 inches, but the general average is about 3½ by 4½ inches. Some 12 tons of mica have been handled, but the amount sold and the average price obtained are not reported. Other localities in New Mexico also yield mica, but none have been developed except the two above mentioned.

Pacific coast.—In California many deposits of mica have been noted, especially at Gold lake, Plumas county; in El Dorado county; Ivanpah district, San Bernardino county; near Susanville, Lassen county, and at Tehachapi pass, Kern county. In 1883 a large deposit was discovered in the Salmon mountains, in the northwestern part of the State, and some prospecting was done.

In Arizona mica is abundant, but is not yet mined. In Nevada it has been noted at many places, especially on Muddy river near the Arizona line, and to the northward of Pyramid lake. Merchantable mica, said to be abundant, has been discovered on the Payette river and Bear creek, and in the Cœur d'Alene region, Idaho; and some of it has been marketed at $3.50 per pound. Mica of workable character is also reported from Oregon and Alaska.

Production.—The output of mica in the United States is increasing. During the last three years the output is estimated as follows:

Production of mica in the United States in 1882, 1883, *and* 1884.

Years.	Pounds.	Value.
1882	100,000	$250,000
1883	114,000	285,000
1884	147,410	368,525

In the foregoing statement the average price of sheet mica marketed is assumed to be $2.50 per pound throughout the three years. This is probably a fair average, for while whole lots often command $3.50 per pound and exceptionally large and clear sheets sell at still higher rates, there is a large proportion which brings only about $2 per pound. The estimates do not include "waste" and ground mica.

The exports of mica and mica goods are insignificant, amounting to only a few hundred dollars' worth annually. Imports during recent years have been:

Unmanufactured mica imported and entered for consumption in the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$1,165	1877	$13,085
1870	226	1878	7,930
1871	1,460	1879	9,274
1872	1,002	1880	12,562
1873	498	1881	5,839
1874	1,204	1882	5,175
1875	....	1883	9,884
1876	569	1884	28,284

ASBESTUS.

Domestic occurrences.—The asbestus used in the United States is in part mined here, in part imported. In this country the mineral is found in very many localities, but usually in pockets or other small deposits. In most cases of occurrence the amount is not sufficient to warrant the expenditure of the capital necessary for opening the deposits; consequently the number of occurrences is far greater than that of operated mines.

The following are the leading localities at which this mineral is obtained: the towns of Brighton, Sheffield, Pelham, and Windsor, Massachusetts; Richmond county and elsewhere in New York; near New Brunswick, New Jersey; near Media and Colerain, Pennsylvania; in the western part of Maryland; Hanover and Loudoun counties, Virginia; western North Carolina; northwestern South Carolina; Rabun and Fulton counties, Georgia; Butte, Fresno, Los Angeles, Tulare, Mariposa, Placer, and Inyo counties, California. It is reported also from Dakota, Wyoming, Colorado, Utah, and Nevada. This list of occurrences might be increased indefinitely, as the mineral is by no means an uncommon one.

The annual production in 1883 and 1884 was about 1,000 short tons. The price in New York ranged from $15 to $40 per ton, the price varying with the quality. The American asbestus is usually characterized by a short fiber, and by being somewhat brittle and harsh. These qualities, while unfitting it to a greater or less extent for such uses as the manufacture of rope, cloth, etc., in which a long fiber is required, do not injure it for the manufacture of paints, cement, packing, etc., for which purposes it is preferred to the imported as being more refractory.

Foreign sources.—Imported asbestus comes mainly from the province of Quebec, Canada, and is perhaps the best for general uses. The better qualities of the Quebec asbestus bring $75 to $100 per ton in New York, while the price of the poorer grades ranges as low as $40 per ton. For the manufacture of cloth, drop curtains, etc., Italian asbestus is principally used, as it has a long, silky, tough fiber, well fitted for the purpose. This brings in New York from $100 to $250 per ton.

Uses.—The uses of asbestus depend upon its refractory qualities, and are being constantly extended. It is used for sheathing, for steam packing, for fireproof paints, cement, and putty, as a lining for safes, for stove pipes, and for fireproof enamel for walls. It is made into yarn, wicking rope, cloth, and paper. Drop curtains for theaters are being made from it, and a demand has recently sprung up for this material for insulation for electric wires.

Value of asbestus imported and entered for consumption in the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Unmanufactured.	Manufactured.	Total.
1869		$310	$310
1870		7	7
1871		12	12
1872			
1873	$18		18
1874	152		152
1875	4, 706	1, 077	5, 783
1876	5, 485	396	5, 881
1877	1, 671	1, 550	3, 221
1878	3, 536	372	3, 908
1879	3, 204	4, 624	7, 828
1880	9, 736		9, 736
1881	27, 717	69	27, 786
1882	15, 235	504	15, 739
1883	24, 369	243	24, 612
1884	48, 755	1, 185	49, 940

Domestic exports of manufactured asbestus.

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1879	$2, 335	1882	$18, 923
1880	7, 848	1883	17, 865
1881	30, 785	1884	30, 846

GRAPHITE.

BY JOHN A. WALKER.

Occurrence.—From the tabulated list of useful minerals in the "Mineral Resources of the United States, 1882," it will be seen that graphite is of too general occurrence to make of special value a list of the localities from which samples are received by the manufacturing companies for examination. During 1884, however, the samples have been numerous and of more promise than usual. There is a growing interest in the mineral, which is becoming so generally used, and about which so little of value has been published. Some of the more recent discoveries would probably have been developed but for the remarkable cheapness of foreign graphite and the general business depression prevailing, especially that of the metal industries, on which the graphite trade largely depends. The importation, while smaller than in any year since 1880, has kept the market fully supplied. These facts, coupled with the difficulty of obtaining men with sufficient knowledge and experience to produce the mineral in a pure state, have delayed the development of any of our more recently discovered deposits, and the Dixon Company continues to be the only successful miner of graphite in the United States. Its mines at Ticonderoga, Essex county, New York, are under the management of Mr. William Hooper, the inventor of some of our best ore-dressing machines, and who has been successful in producing from a 10 per cent. ore the finest graphite in the world.

Graphite has been observed in many places throughout the Pacific States and Territories; only in California, however, where its occurrence seems most frequent, have any attempts been made to mine and market or otherwise utilize it in a large way. The deposit which has been most worked in that State is situated one mile north of the town of Sonora, Tuolumne county, from which some twenty years ago about 1,000 tons of graphite were extracted, the most of which was shipped to England, France, and Germany, and there sold at the rate of about $100 per ton, a price that afforded the shippers some profit. But the impossibility of securing here any large quantity sufficiently pure for commercial purposes put an end to the enterprise, the labor of concentrating the crude material, which was largely mixed with slate and other foreign matter, having been expensive. Besides the Sonora deposits, graphite has been found in California at the following places: Near Summit City, Alpine county; on the border of Tomales bay in the Coast range of Marin county; near Fort Tejon, Kern county; at Tejunga, Los Angeles county, and at Boser hill, Fresno county (both recent discoveries), and at several places in Sierra, Plumas, Marin, and Sonoma counties. In 1883 a deposit of graphite was found in the Sierra mountains, Humboldt county, Nevada. The mineral here occurs in numerous small veins, some of it being quite pure; but like the deposits elsewhere on the Pacific coast, this possesses just now no special value. Graphite has also been found recently in Beaver county, Utah, but the quality of the mineral and the extent of the deposit remain to be tested. A deposit in Albany county, Wyoming, is reported as about 20 inches thick and sufficiently pure to be worked; no developments have been made, and the extent of the deposit is unknown.

Production.—During 1883 the Ticonderoga mines produced 550,000 pounds, and estimating the output of various other workings at 25,000 pounds, the total production for 1883 was 575,000 pounds, representing, at an everage spot value of 8 cents per pound, $46,000. The output in 1884 was practically nothing. The accumulated stocks and the industrial depression caused the suspension of work at the Ticonderoga mines during 1884, and it is not known that any other mine was operated on a commercial scale. The year 1885 will, however, witness the early reopening of the Ticonderoga mines, and active work during the whole of the year may be looked for.

Imports.—The following table shows the quantity and value of graphite imported and entered for consumption in the United States from 1867 to 1884, inclusive:

Graphite imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Unmanufactured.		Manufactured.	Total.
	Quantity.	Value.		
	Cwts.			
1867	27,713	$54,131		$54,131
1868	68,620	149,083		149,083
1869	74,846	351,004		351,004
1870	80,795	269,291	$833	270,124
1871	51,628	136,200	3,754	139,954
1872	96,381	329,030		329,030
1873	157,539	548,613		548,613
1874	111,992	382,591		382,591
1875	46,492	122,050		122,050
1876	50,589	150,709	17,605	168,314
1877	75,361	204,630	18,091	222,721
1878	60,244	154,757	16,909	171,666
1879	65,662	164,013	24,637	188,650
1880	109,908	278,022	22,941	300,963
1881	150,927	381,966	31,674	413,640
1882	150,421	363,835	25,536	389,371
1883	154,893	361,949	21,721	383,670
1884	144,086	286,393	1,863	288,256

Exports.—Very little crude domestic graphite is exported. This will not appear strange when it is considered that the domestic mines in 1883 provided only 575,000 pounds, while 17,348,016 pounds were imported. Statistics show for the ten years 1875 to 1884, inclusive, a total export of less than $20,000 worth. Figures of the export of manufactured domestic graphite are difficult of statement, from the fact that graphite forms a partial ingredient in so many kinds of goods. The custom-house records show, for instance, the following figures: Exports of manufactured graphite of domestic production for the fiscal year 1881, $1,066; for 1882, $4,834; while for most years no exports are specified. The records are obviously imperfect, as a single company in each of these years exported domestic graphite products of larger value. An approximate statement is the only thing possible; $25,000 per annum will cover the value of the graphite in articles manufactured from the domestic product, while $50,000 per annum will probably cover the value of the articles.

Manufactures.—The properties of graphite specially fit it for the following purposes: The manufacture of refractory articles, such as crucibles, retorts, dippers, stirrers, bricks, stoppers, nozzles, foundry facings, etc.; lubricating compounds, electrical supplies, stove-polish, electrotyping "lead," pencil leads, and pigments. The table of relative proportions of different kinds of graphite used, and the percentage consumed for each of the various purposes, given in the last report, must be changed somewhat on account of the increased use of graphite as a lubricant and in the manufacture of foundry facings.

Proportionate amounts and kinds of graphite used for different purposes.

Manufactures.	Kinds of graphite used.	1883.	1884.
		Per cent.	*Per cent.*
Refractory articles, such as crucibles, retorts, stoppers, etc.	Ceylon, American	35	30
Stove polish	Ceylon, American, German	32	30
Lubricating graphite	American, Ceylon	10	13
Foundry facings, washes, etc	Ceylon, American, German	8	10
Graphited greases	American	6	8
Pencil leads	American, German	3	3
Graphited packing	Ceylon, American	3	3
Polishing gunpowder and shot	Ceylon, American	2	2
Paint	American	½	½
Electrotyping	American, Ceylon	¼	¼
Miscellaneous—piano action, photographers' and hatters' use, electrical supplies, etc.		¼	¼
		100	100

The foregoing table shows quite an increase over the similar table of the former report in the percentage used for lubrication and manufacture of foundry facings and washes. These two lines deserve especial mention.

Graphite in foundry facings.—The last few years have witnessed a great improvement in American foundry practice. From the comparatively light, simple, and rough castings of the earlier days, the time has been reached when immense castings are of frequent occurrence, in which the work is often elaborate and the finish is very high; in fact, castings are now produced at will, light or heavy, smooth or rough, plain or ornate, of common, chilled, or malleable iron, steel, etc., and all of these different conditions require different service of the facings. Instead of the simple hard-wood charcoal-dust of earlier times, facings of charcoal, sea coal, anthracite, soapstone, and "black lead" or graphite are now used. In all cases where the work is severe, graphite is the constituent which gives the "body," the "sleeking" and "peeling" properties, to the facing. The use of graphite for this purpose has increased rapidly with the demand for better and finer foundry work.

Graphite as a lubricant.—With the introduction of heavier machinery the service demanded of a lubricant has become more and more severe. For much of this work it is found that oil will not answer at all, and for much more it answers only at great expense; hence the use of greases and the more solid lubricants, such as graphite, mica, soapstone, sulphur, etc. When graphite first began to be used as a lubricant anything which gave a stove-polish luster when rubbed was assumed to be "black lead" and fit for lubricating purposes. Experience soon proved it to give very varied results—sometimes very good and sometimes the reverse; in fact, it was not reliable because of a lack of uniform, correct sizing and purity, and soon fell in disrepute among practical men, though continuing to be well spoken of in the books. In 1868, however, systematic experiments were begun in this country with a view to producing a reliable lubricant from graphite, and the final result has been very satisfactory.

Water-dressed dry foliated American graphite is a little thin flake of graphite of extraordinary properties. Its superiority as a lubricant has been attested by all recent writers on friction. Its co-efficient of friction is very low. Its enduring qualities are several times greater than those of any oil. Unlike either oil or grease, it is not affected by heat, cold, steam, acids, etc., and acts equally well under varying conditions of temperature and moisture.

Many and carefully conducted experiments in the laboratory with Professor Thurston's testing machine, and experience in shops, have shown that for the highest usefulness the flake must be of a certain size and dressed perfectly pure. Graphite never occurs of the proper size and purity for use. Its natural impurities contain substances fatal to anti-friction purposes. Its proper selection, sizing, and perfecting for lubricating purposes is a matter requiring large skill, much machinery, and great experience. The difference between a perfectly pure graphite and one almost pure, but still totally unfit for lubricating, cannot be detected by either sight or touch.

It is recommended dry for steam and air cylinders, mixed with grease for heavy bearings, and mixed with oil for light bearings. On being applied to a bearing it readily coats the surfaces with a shiny, unctuous veneer. These surfaces then slide on each other with very little friction. On being applied to heated bearings the graphite soon fills up any inequalities of the bearing surfaces due to cutting, abrasion, etc., making them smooth and even, after which the bearing soon cools down. It is equally useful for wood or metal surfaces; in short, in all cases where friction exists. If the bearings are loose enough for the introduction of this thin flake graphite, it will prevent heated bearings, cool those already heated, and reduce friction better than anything else. In all cases where the service required of a lubricant is very severe, graphite will be found specially useful, as in mill steps, gears, heavy bearings, bed plates, etc.

Table of tests.

Lubricant.	Quantity in milligrams.	Total pressure in pounds on bearing.	Temperature at the close, °F.	Average co-efficient of friction.	Time in minutes till the bearings "squealed."	Total number of feet friction surface traveled.
Best sperm oil	335	180	240°	.0555	11	7,198
Graphite mixed with enough water to distribute it over bearings	120	180	234	.0596	30	19,635
Graphite mixed with tallow	335	120	340	.0936	38	24,216

This is the most rapidly growing use of graphite. In 1884 a single company sold 250,000 pounds of it for this purpose, branded as "lubricating graphite," and probably as much more not so labeled, which was used for the same purpose.

A French engineer is said to have recently introduced a new refractory brick, made by agglomerating powdered graphite, for metallurgical purposes.

List of American manufacturers.

House.	Location.	Articles made.
Joseph Dixon Crucible Company	Jersey City, New Jersey	Everything for which graphite is used.
Phœnix Crucible Company	Taunton, Massachusetts	Crucibles.
Taunton Crucible Company	do	Do.
J. H. Gautier & Co	Jersey City, New Jersey	Do.
R. Taylor & Co	Philadelphia, Pennsylvania	Do.
Seidell & Co	do	Do.
Ross & Co	do	Do.
Hussey & Co	Pittsburgh, Pennsylvania	Do.
A. W. Faber	New York City	Lead pencils.
Eagle Pencil Company	do	Do.
American Lead Pencil Company	do	Do.
Cutter & Brown	do	Foundry facings.
Variety Iron Works	Cleveland, Ohio	Facings, etc.
S. Obermayer & Co	Cincinnati, Ohio	Facings, lubricants.
Morse Bros	Canton, Massachusetts	Stove polish.
J. L. Prescott & Co	North Berwick, Maine	Do.
American Chemical Manufacturing and Mining Company.	Rochester, New York	Do.
Ransom & Co	Albany, New York	Facings.
W. H. Colebrook	Syracuse, New York	Stove polish.
G. A. Moss	New York City	Do.
Lustro Company	do	Do.
H. A. Bartlett & Co	Philadelphia, Pennsylvania	Do.
Willard & Lane	Taunton, Massachusetts	Do.
I. X. L. Stove Polish Company	Grand Rapids	Do.
Phœnix Mining Company	Philadelphia, Pennsylvania	Stove polish and lubricants (mining).
A. Z. Ryerson	Bloomingdale, New Jersey	(Mining).

MINERAL PAINTS.

The information contained in the following notes has been furnished through the courtesy of the *Oil, Paint, and Drug Reporter*, of New York City, with some additions from other sources. Acknowledgment is also due Mr. Marcus Benjamin and Dr. I. W. Drummond.

The principal mineral substances used in the manufacture of paints are:

White—White lead, zinc white, barytes, blanc fixe, terra alba, china clay, whiting, and Paris white.

Red—Vermilion and red lead.

Yellow—Potassium bichromate (used in the manufacture of chrome yellow, etc.), ocher, and litharge.

Brown—Ocher, umber, and sienna.

Blue—Ultramarine.

White lead.—White lead, the most important of all the white pigments, is largely made in this country. The pig lead from which it is produced is obtained from the lead refiners, of whom a list is given on page 427. The lead is then corroded. There are about thirty-one corroders, or white-lead works, in this country, distributed as follows: Boston, Massachusetts, 2; Buffalo, New York, 1; New York City, 5; Philadelphia, Pennsylvania, 3; Pittsburgh, Pennsylvania, 6; Baltimore, Maryland, 1; Saint Louis, Missouri, 3; Louisville, Kentucky, 2; Dayton, Ohio, 1; Cincinnati, Ohio, 3; Cleveland, Ohio, 1; Chicago, Illinois, 2; and San Francisco, California, 1. The process used is generally known as the "Dutch method." Its essential features are as follows: The pig lead is cast into perforated "buckles" 7 inches in diameter and $\frac{1}{8}$ inch thick. These buckles are packed in earthenware pots about 15 inches high and of suitable diameter for the reception of the buckles. A dilute solution of acetic acid is poured into the pots, which are piled in bins, or stacks, 40 feet square. When the stack is completed it is covered with spent tan bark or manure and then left alone for about 30 days. A chemical decomposition of the lead follows in consequence of the heat generated, and the metallic pig becomes converted into the white carbonate. The unloading of the stack then takes place, with the removal of the contents of the pots, which is partially lead carbonate (white lead) and partially unconverted pig lead. The mixture is thrown into a revolving drum which retains the metallic portion and allows the white lead to pass through a screen. The quantity of pig lead converted into white lead never amounts to more than 60 or 70 per cent. There is always a residue of unconverted lead. The composition of white lead is not constant. The amount of lead oxide (PbO) varies from 84.7 to 86.5 per cent., with correspondingly differing amounts of carbonic acid (CO_2) and water (H_2O). During 1884 about 65,000 tons of white lead were manufactured in this country. The price varied from 4½ to 5¼ cents per pound for the dry pigment, and for that in oil the price ranged between 4¾ and 5¾ cents per pound in the eastern markets. In the West it was a quarter of a cent lower. A small amount, 665,183 pounds, of white lead, was imported into New York during 1884. It is higher in price than the American, selling at from 8½ to 8¾ cents per pound. It is imported chiefly from England.

A so-called "sublimed lead" is prepared by a patented process, the principle of which is the direct oxidation of the crude lead sulphide (galena) on the hearth of a reverberatory furnace, giving rise to a lead sulphate. It is made in Joplin, Missouri, for John T. Lewis & Brother, of Philadelphia.

White lead imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	6, 636, 508	$430, 805	1876	2, 546, 766	$175, 777
1868	7, 533, 225	455, 698	1877	2, 644, 184	174, 844
1869	8, 948, 642	515, 783	1878	1, 759, 608	113, 639
1870	6, 228, 285	365, 706	1879	1, 274, 196	76, 062
1871	8, 337, 842	483, 392	1880	1, 906, 931	107, 105
1872	7, 153, 978	431, 477	1881	1, 068, 030	60, 133
1873	6, 331, 373	408, 986	1882	1, 161, 889	64, 494
1874	4, 771, 509	323, 926	1883	1, 044, 478	58, 589
1875	4, 354, 131	295, 642	1884	902, 281	67, 919

Zinc white.—Zinc white, second only to white lead in importance as a white pigment, is extensively manufactured in this country. It is made directly from zinc ore by the following companies: New Jersey Zinc and Iron Company, Newark, New Jersey; Passaic Zinc Company, Jersey City, New Jersey; Bergen Port Zinc Company, Bergen Port, New Jersey; Lehigh Zinc and Iron Company, Bethlehem, Pennsylvania; Page & Krause Manufacturing and Mining Company, Saint Louis; and the Mineral Point Zinc Company, Mineral Point, Wisconsin. It is estimated that during 1884 the output of these works was between 12,000 and 15,000 tons. The price of the zinc white was from 3 to 4 cents per pound, according to the quality, which is determined by its whiteness and body. In addition to its use as a pigment it is employed in the manufacture of rubber, of pottery, and of various kinds of paper. The imported zinc white is chiefly made by the Societé Anonyme de la Vieille Montagne, whose works are in the Liège district, Belgium. Three grades of this pigment are imported into this country: (1) the "Paris green seal," (2) the "Paris red seal," and (3) the "Antwerp red seal." According to its quality it is worth from 5½ to 8½ cents per pound. A small quantity of the zinc white ground in oil is likewise imported. At New York the importations during 1884 were 1,898,452 pounds. The quality of the French zinc oxide is considered superior to the American grade in purity of color. A small proportion, some 330,000 pounds, of a German zinc white, known as the "L. Z. O." brand, was imported into New York during 1884. It sells at from 6 to 6⅛ cents per pound.

Oxide of zinc (*a*) *imported and entered for consumption in the United States,* 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	1,569,322	$91,330	1876	2,460,144	161,944
1868	1,954,485	95,518	1877	2,068,729	130,719
1869	1,849,208	105,844	1878	2,451,060	140,157
1870	2,064,234	113,254	1879	2,274,935	117,886
1871	2,075,898	103,493	1880	2,288,604	123,113
1872	3,660,091	193,448	1881	2,044,778	106,990
1873	3,530,465	233,421	1882	2,538,090	125,599
1874	1,974,469	136,282	1883	1,877,804	93,987
1875	2,800,998	181,455	1884	3,143,784	141,961

[a] Presumed to be dry oxide, not ground in oil. In 1884 the imports of zinc oxide ground in oil were 116,135 pounds, valued at $6,856.

Barytes.—This mineral (heavy spar, barite, barium sulphate) is abundant in many parts of the country, and is mined in considerable quantities in the following States, named in the order of their production: Missouri, Virginia, Tennessee, North Carolina, and Connecticut. It is difficult to form even an approximate estimate of the production, owing in part to the reticence of manufacturers and dealers. It is probable, however, that it was in 1883 and in 1884 between 25,000 and 30,000 tons. The value of crude barytes ranged from $1.50 to $5 per ton at the mines, varying with the quality and the proximity to market. Crude barytes is ground by several firms, but chiefly by Burgess & Newton, of New Haven. Of the ground material, the price in 1883 ranged from $15 to $22 per ton, and in 1884 from $12 to $20; the best quality bringing $18 to $20, while the inferior grade sold at from $12 to $15.

Barytes is imported from England, Ireland, Germany, Canada, and Nova Scotia. The imported mineral in lumps is worth from $6 to $10 per ton. The expense of manufacturing is about $7.50 per ton. It is estimated that at least 10,000 tons of barytes were used in New York during 1884, of which one-half was consumed by the paint manufacturers. As regards quality, the American is considered equal, if not superior, to the imported, the domestic mineral being softer and smoother. Much of the American barytes has been found in pocket deposits, and therefore the amount and quality cannot always be depended upon. At Saint Louis, Missouri, the Page & Krause Manufacturing and Mining Company prepare a "floated barytes" which is in considerable demand. The ground mineral is floated in long sluiceways, and that which floats the farthest is the finest. This variety of barytes is found to be much finer than that which is simply ground, but it is liable to be a little less white in color, as it takes some of the coloring matter from the water with which it is treated. It sells at from $30 to $32.50 per ton.

Besides its large consumption in the manufacture of paint, baryta is used in the form of peroxide in bleaching and in the form of nitrate in fireworks. It is used largely as an adulterant, especially as a make-weight.

Blanc fixe, also known as permanent white and barytic white, is artificial barytes. The crude heavy-spar is thoroughly ground and mixed with some carbonaceous material, such as coal dust, and some chlorine compound, generally the residue from chlorine stills. This mixture is treated in a reverberatory furnace for an hour. The resulting mass is lixiviated, and the liquor, which is a solution of almost pure barium chloride, is drawn off and mixed with sulphuric acid. The resulting precipitate, which is barium sulphate in an exceedingly fine state of division, constitutes blanc fixe. It is generally sold in pulp (that is, ground in water) at a price ranging from 2⅝ to 2¾ cents per pound. Its covering power is much greater than that of the natural barytes. It is manufactured in New York. Besides its application as a paint it is used by calico printers, card makers, and in the manufacture of paper. There is very little, if any, difference between the imported and American-made article.

Barytes, etc., imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Barytes.		Nitrate of baryta.	Baryta.
	Quantity.	Value.		
	Pounds.			
1867	14, 968, 181	$141, 273	$383	....
1868	2, 755, 547	26, 739	852	....
1869	1, 117, 335	8, 565	1, 454	$550
1870	1, 684, 916	12, 917	1, 770	4, 061
1871	1, 385, 004	9, 769	144	2, 035
1872	5, 804, 098	43, 521	2, 291	....
1873	6, 929, 425	53, 759	3, 397	....
1874	4, 788, 966	42, 235	1, 561	....
1875	2, 117, 854	17, 995	5, 881	....
1876	2, 655, 349	25, 325	6, 451	....
1877	2, 388, 373	19, 273	6, 267	[b]96
1878	1, 366, 857	10, 340	6, 354	....
1879	453, 333	3, 496	8, 556	....
1880	4, 924, 423	37, 374	12, 586	....
1881	1, 518, 322	11, 471	2, 717	....
1882	562, 300	3, 856	1, 920	....
1883	411, 666	2, 489	997	....
1884	5, 306, 443	19, 083	(a)	....

[a] Not specified. [b] Not specified since 1877.

The imports in 1884 consisted of:

	Pounds.	Value.
Manufactured sulphate of baryta	2, 721, 361	$15, 417
Unmanufactured sulphate of baryta	2, 585, 082	3, 666
Total	5, 306, 443	19, 083

Blanc fixe, satin white, enameled white, lime white, and all combinations of barytes with acids or water, imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.
	Pounds.	
1867	445, 310	$12, 615
1868	177, 995	5, 876
1869	182, 984	6, 292
1870	97, 643	4, 672
1871	147, 464	5, 910
1872	70, 469	5, 091
1873	119, 972	4, 457
1874	118, 384	4, 079
1875	145, 728	4, 899
1876	15, 744	$2, 091
1877	4, 500	809
1878	4, 955	1, 048
1879	1, 993	329
1880	4, 400	752
1881	11, 330	2, 027
1882	52, 364	1, 781
1883	28, 525	1, 232
1884	71, 059	8, 814

Terra alba is ground gypsum (see also page 809). The gypsum used for this substance is entirely imported from Nova Scotia. The mineral is ground at two places, Newburgh and New York City. Gypsum for this purpose is imported in two qualities. The best (or No. 1) is worth from $5 to $7 per ton; the poorer quality (or No. 2) is worth from $3 to $4 per ton. After it has been ground it is worth for No. 1 from $14 to $15 per ton, and for No. 2 from $8 to $10 per ton. A finer grade, worth from $18 to $20 per ton, is imported from France. During 1884 4,132,784 pounds were imported at New York. The amount of American terra alba annually produced is estimated to be slightly less than that of the imported. It is used in making cheap white pigments and as a weighting substance or adulterant for many purposes.

Terra alba imported and entered for consumption in the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Aluminous.		Not aluminous.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Pounds.		*Pounds.*		
1869				$7, 002	$7, 002
1870				7, 911	7, 911
1871				133, 028	133, 028
1872				6, 444	6, 444
1873		$44, 994		2, 235	47, 229
1874		56, 821		1, 029	57, 850
1875		45, 726			45, 726
1876		20, 876		27, 897	48, 773
1877		345		45, 471	45, 816
1878		683		33, 509	34, 192
1879		7, 081		33, 250	40, 331
1880		14, 737		34, 718	49, 455
1881		9, 797		30, 186	39, 983
1882	12, 008, 101	30, 522	283, 046	1, 572	32, 094
1883	10, 592, 552	19, 533	149, 782	800	20, 333
1884	10, 066, 496	25, 188			25, 188

China clay.—See page 676.

Whiting.—See page 931.

Paris white.—See page 930.

Vermilion.—See page 501.

Red lead.—(See also page 971.) Red lead or minium is an artificially-produced oxide of lead manufactured by lead refiners and corroders.

No estimate of the amount produced could be obtained. The demand during 1884 is said to have been somewhat less than that of the previous years, owing to the fact that several factories, where considerable quantities of this pigment were employed, were closed. The price was from 5¼ to 5½ cents per pound. Some 198,588 pounds of red lead were imported into New York during 1884. In quality the American article is claimed to be fully equal to the imported, but for some few purposes there is a slight demand for the foreign material. The imported is a little higher in price, selling at from 7¼ to 7¾ cents per pound.

Red lead imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	926, 843	$53, 087	1876	749, 918	$54, 884
1868	1, 291, 144	76, 773	1877	387, 260	28, 747
1869	808, 686	46, 481	1878	170, 608	9, 364
1870	1, 042, 813	54, 626	1879	143, 237	7, 237
1871	1, 295, 616	78, 411	1880	217, 033	10, 398
1872	1, 513, 794	85, 615	1881	212, 423	10, 009
1873	1, 583, 089	99, 891	1882	288, 946	12, 207
1874	756, 644	56, 306	1883	249, 145	10, 503
1875	1, 084, 713	73, 132	1884	265, 693	10, 589

Potassium bichromate.—See page 572.

Litharge.—No figures of the production or consumption of this pigment are available. It is manufactured by lead refiners and corroders. A diminished consumption during 1884 is said to have occurred, on account of the depression of business causing several factories, where large amounts of litharge were used, to close their works. The price changed but little; it has sold at from 5¼ to 5¾ cents per pound. A limited quantity of English litharge, some 28,149 pounds, was imported at New York during 1884. As regards quality, the American is claimed to be fully equal to the foreign.

Litharge imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	230, 382	$8, 941	1876	47, 054	$2, 562
1868	250, 615	12, 225	1877	40, 331	2, 347
1869	187, 333	7, 767	1878	28, 198	1, 499
1870	97, 398	4, 442	1879	38, 495	1, 667
1871	70, 889	3, 870	1880	27, 389	1, 222
1872	66, 544	3, 396	1881	63, 058	2, 568
1873	40, 799	2, 379	1882	54, 592	2, 191
1874	25, 687	1, 440	1883	34, 850	1, 312
1875	15, 767	950	1884	54, 183	1, 797

Ocher.—Ochers are hydrated oxides of iron containing varying proportions of ferric oxide and water. The term has also come to include earthy mixtures of silica and alumina with oxide of iron and sometimes calcareous matter and magnesia. "Indian red" was originally a term given to a mineral found in the Persian gulf, and used as a pigment. The hard coarse powder had a dark red color with a tinge of purple. It contained:

	Per cent.
Ferric oxide	56.59
Silica	30.17
Alumina	3.79
Lime	2.65
Magnesia	1.43
Sulphur dioxide	2.28
Carbonic acid	1.73
Moisture	1.62
	100.26

The ocher deposits of this country may be said generally to exist wherever iron ore is mined. There are many localities that are worked in Vermont, Pennsylvania, Wisconsin, Georgia, Alabama, and in several of the western States. The deposits of Brandon, Vermont, are well known. At Bermuda Hundred, Virginia, about 1,000 tons are annually produced, having a value at the mine of $22.50 per ton. A locality near Saint Louis, Missouri, is said to yield an ocher equal to the best imported, and it is valued at $30 to $35 per ton. The price of the poorer grades of ocher is from $7 to $10 per ton, while the better qualities are sold at from $15 to $30 per ton. The latter price is for finely-powdered ocher, barreled and delivered in New York. Paint factories, where the crude pigment is ground into paint with oil, are found in most of the large cities; in Portland, Boston, New York City, Philadelphia, Baltimore, Saint Louis, Cincinnati, Cleveland, Chicago, Pittsburgh, and San Francisco. Many of these factories own or lease deposits which are worked for their exclusive use. Ochers are also found in all countries, but the most celebrated and those chiefly used in painting are the ochers coming from the south of France (St. Georges sur la Près, Vierzon, and Saint Amand); from Italy; from England (Shotover hills, near Oxford), and also from some parts of Germany. The importation of ocher at New York in 1884 was 5,658,703 pounds. The foreign ochers are considered superior to the American, with the possible exception of the recently-opened deposits near Saint Louis. The lower grades of French ocher are poor, and perhaps may be placed lower than the best Bermuda Hundred ochers. The American ochers for the most part lack strength or tinting properties, and they require too much oil for grinding. An ocher requiring only 25 per cent. of oil to grind it into a paste is naturally much more economically made into paint than one requiring 50 per cent. of oil, even though the price of the crude ocher be greater. The annual consumption of ocher in the United States is estimated to be about 10,000 tons, of which some 3,000 tons are imported. The following tables show only partial imports, according to the custom-house classification, part of the ocher being reported under special trade names:

Ocher and ochery earth, dry, imported and entered for consumption in the United States in 1882, 1883, *and* 1884.

Fiscal years ending June 30—	Quantity.	Value.
	Pounds.	
1882	5, 530, 204	$68, 106
1883	7, 022, 615	90, 593
1884	6, 285, 588	70, 191

Ocher, ground in oil, imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	11, 373	$385	1876	63, 916	$3, 365
1868	6, 949	383	1877	41, 718	2, 269
1869	65, 344	2, 496	1878	25, 674	1, 591
1870	149, 240	6, 042	1879	17, 649	1, 141
1871	121, 080	4, 465	1880	9 , 293	4, 233
1872	277, 617	9, 225	1881	99, 431	4, 676
1873	94, 245	3, 850	1882	159, 281	7, 916
1874	98, 176	4, 624	1883	137, 978	6, 143
1875	280, 517	12, 352	1884	156, 295	5, 233

Indian red and Spanish brown imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	....	$35, 374	1876	1, 524, 989	$19, 555
1868	....	11, 165	1877	2, 179, 631	24, 218
1869	2, 582, 335	31, 624	1878	2, 314, 028	23, 677
1870	3, 377, 944	41, 607	1879	2, 873, 550	26, 926
1871	2, 286, 930	40, 663	1880	3, 655, 920	32, 726
1872	2, 810, 282	38, 763	1881	3, 201, 880	30, 195
1873	135, 360	2, 506	1882	3, 789, 586	34, 136
1874	263, 389	3, 772	1883	1, 549, 968	13, 788
1875	646, 009	9, 714	1884	(*a*)	47, 762

a Not specified.

Umber.—Umber is a naturally occurring mixture of limonite (hydrated ferric oxide) and hydrated manganese ore with clay. A little has been mined in Pennsylvania and some in Vermont. Certain mineral pigments are sometimes mixed so as to produce an artificial umber. Its color and depth of hue compare unfavorably with the imported umber. The American umber is usually cold and gray, while the imported is rich, warm, and reddish. It is shipped principally from Leghorn, Italy. Umber is found in beds with brown jasper in the island of Cyprus, and it also occurs in certain parts of Turkey. Laid down in New York it is valued at $22.50 to $30 per ton. Umber is used by painters as a brown color.

Umber imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	2, 147, 342	$15, 946	1876	681, 199	$7, 527
1868	345, 173	2, 750	1877	1, 101, 422	10, 213
1869	570, 771	6, 159	1878	1, 038, 880	8, 302
1870	708, 825	6, 313	1879	986, 105	6, 950
1871	470, 392	7, 064	1880	1, 877, 645	17, 271
1872	1, 409, 822	18, 203	1881	1, 475, 835	11, 1[illegible]6
1873	845, 601	8, 414	1882	1, 923, 648	20, 494
1874	729, 864	6, 200	1883	785, 794	8, 419
1875	513, 811	5, 596	1884	*a*2, 946, 675	20, 654

a Dry umber. In addition, 4,779 pounds, ground in oil, valued at $127, were imported.

Sienna.—Sienna is a name given to a clay colored by the peroxides of iron and manganese. Siennas are mined to a very slight extent in Virginia and Pennsylvania, and in Canada. Most of the material used in the manufacture of paints is imported from Italy. Sienna is never burnt in this country, but is imported in lumps either raw or burnt. Its value is from 4 to 6 cents per pound. The imports at New York during 1884 were 392,119 pounds.

Ultramarine.—This most beautiful of all blue pigments is obtained from lapis lazuli, a mineral of somewhat rare occurrence. The finest samples of this stone are obtained from Persia, Lake Baikal in Siberia, Bokara, and more recently from China. Only from 2 to 3 per cent. of the purest article can be obtained from the best stone, and the pigment is therefore very expensive, costing sometimes more than $100 an ounce. A very small quantity is imported into this country and ground into paint for artists' use.

The artificial preparation known as ultramarine is largely employed as a pigment. It is composed approximately of 46.60 per cent. silica, 23.30 alumina, 3.83 sulphuric acid, 21.48 soda, 1.06 iron oxide, and traces of lime, sulphur, and magnesia. The ingredients employed are sometimes china clay, sodium sulphate, charcoal or pit coal, and rosin; or china clay, soda, silica, sulphur, and rosin. Their proportions are a matter of secrecy, but may be deduced pretty accurately from the percentage of composition just given. The raw materials are ground very fine, well mixed and pressed, and calcined in muffle furnaces at a red heat for 12 to 36 hours or until the sulphur is nearly burnt off. When the firing is complete the furnaces are closed tightly and the material is allowed to cool, requiring five to six days. The product is first green ultramarine, which during the cooling process changes into a dark blue. After washing it is ground in wet mills for from two to five days, settled under the action of heat, repeatedly washed, classified, dried, bolted, and packed. In this country there are two factories of this pigment—the American Ultramarine Works at Newark, New Jersey, and the Germania Ultramarine Works at Whitestone, Long Island. In the preparation of the pigment these factories use principally three articles: (1) English clay, imported from Cornwall, England, which costs from $15 to $18 per ton landed in New York. An American clay, costing from $10 to $12 per ton, has been somewhat used. (2) Sulphur, which comes mainly from Sicily. A little has been imported from Japan, only as an experiment, however. (3) Soda ash, imported from England. Of each of these three substances about 750 tons are consumed annually for this purpose. A small amount of American rosin is used, and the sand employed is likewise domestic. The output of the two factories during 1884 is estimated to have been 1,400 tons; while 312 tons were imported into New York during the same time. The price varies, according to the purity, brilliancy, and strength of color, from 2½ cents up to as high as 50 cents per pound; the average price, however, is between 8 and 12 cents. The American brands compare quite favorably with the imported. Considerable prejudice existed for a long time against the domestic preparation, but this is now gradually disappearing. The principal foreign manufactories are in Germany, but ultramarine is also made in Austria, Belgium, France, and England.

Ultramarine imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	....	$78,490	1876	1,394,697	$191,606
1868	....	96,638	1877	1,559,027	203,763
1869	....	72,101	1878	1,279,297	162,487
1870	....	92,174	1879	1,020,003	131,762
1871	....	92,142	1880	1,214,770	162,653
	170,947	23,674	1881	913,935	127,352
1872	670,839	86,997	1882	906,684	122,988
1873	1,037,949	136,908	1883	819,625	105,654
1874	1,257,637	165,634	1884	1,015,875	114,228
1875	1,468,487	203,773			

Slate and shale.—Roofing slate is included under the head of Building Stone, page 662. Slate, and also some shale, are used to a limited extent as pigments after grinding. Messrs. Ilsley, Doubleday & Co., of New York City, mine at Grafton, near Troy, New York, a slate or shale which they grind and sell as a pigment. Their output is about 2,000 tons per year, which is said to be less than the demand. It sells at from $10 to $15 per ton, according to quantity. This substance comes in four colors: green, slate, red, and drab. The ground pigment is mixed in oil by the purchasers according to their wants. It is employed in the preparation of certain roofing paints, as a backing for oilcloths, as a "filler" or first coat in some methods of outside painting, and to a small extent for the same purpose in coach painting. It is also used in the same way on a small scale in England, and is exported to that country in small lots. It is claimed to make a durable paint, but it takes up a large quantity of oil in grinding. In addition to the manufacture in New York State, it is reported that slate is produced for similar purposes at Green Bay, Wisconsin, and possibly elsewhere.

CHALK.

No chalk is quarried in the United States. Some scattered deposits have been found, but the cost of transportation to a market has hitherto prevented competition with the imported chalk. The mineral is so cheap and easily mined that, the supply being imported as ballast or at low rates, the domestic chalk, which would have to be carried over considerable distances by rail, is under present conditions at a disadvantage. The imports come almost entirely from Great Britain, with small quantities from Dieppe and Rouen in France. The Swedish chalk cannot compete with that from England on existing terms of transportation.

The products from the imported chalk are common whiting, gilders' whiting, paris white, and prepared chalk drops, besides which there is a small quantity, perhaps a thousand tons a year, used in the manufacture of chemicals.

At the close of the year 1884 the price of chalk in New York was about $1.25 by steamer and $1.70 by sail per long ton of 2,240 pounds, invoice weight at the quarry, the difference in price being caused by the steamer chalk having to be lightered, while that of the sailing vessel is unloaded directly on the dock. The foregoing are the prices ruling under the lowest conditions. As an average, it may be said that the importing price has ranged between $2 and $3.50 per long ton, wet, while the selling price of kiln-dried chalk has been $5 to $8 per short ton.

Paris white is the name given to the white coloring substance prepared by grinding cliffstone, a variety of chalk or limestone which is as hard as some building stones and has a greater specific gravity than the ordinary chalk. It is imported from Hull, England, and sells at from $2 to $4 per ton ex vessel, according to freight rates from Hull. During the calendar year 1884 3,905½ tons of cliffstone were imported at New York. The paris white made in this country is sold at from $1.10 to $1.25 per hundredweight, in casks, according to make and quality. The paris white made in England, of which 508,185 pounds were imported at New York during the calendar year 1884, sells at from $1.25 to $1.30 per hundredweight. There is apparently no difference in quality between the cliffstone ground in this country and the imported paris white. Its principal use is in the preparation of kalsomine. It is also employed in the manufacture of rubber, oil-cloth, wall papers, and fancy glazed papers. The makers of paris white from English cliffstone are: H. F. Taintor, C. T. Raynolds & Co., and Phillips & Ferguson, of New York City; George Hasse (proprietor of the Richmond Refining Works), Holt & Duncan, Leatherman & Brother, and J. W. Graffley & Brother, of Philadelphia.

Whiting or ground chalk.—All of the whiting used in this country is ground from chalk imported from Hull, England. The annual production of whiting is about 300,000 barrels. The price varies according to the quality, from 35 to 90 cents per hundredweight. There are four grades made, as follows: Common whiting, worth from 35 to 40 cents; gilders' whiting, 60 to 65 cents; extra gilders' whiting, 70 to 75 cents; American paris white, 80 to 85 cents. The uses of whiting are about the same as paris white, which it closely resembles. The manufacturers of whiting in the United States are: Messrs. C. T. Raynolds & Co., Truslow & Co., H. F. Taintor, John J. Budd, Frank Malone & Co., John N. Koster, William B. Weddle, Arthur Buel, and Phillips & Ferguson, of New York City; E. V. Crandall, Brooklyn; Conrad Zeiger, Williamsburg; W. S. Pratt & Co., of Boston and Philadelphia; J. W. Stickney & Co., Boston; Southwark Manufacturing Company, J. W. Graffley & Brother, Holt & Duncan, Leatherman & Brother, and Kelley, Brother & Spielman, of Philadelphia—all of the Philadelphia makers being represented by the Quaker City Whiting Company.

Imports and exports.—The re-exports of chalk and exports of preparations of chalk are small. Recent imports have been as follows, the values being the declared foreign values:

Chalk imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	White and cliffstone.		All other, not otherwise specified.		Total value.
	Quantity.	Value.	Quantity.	Value.	
	Cwts.		*Pounds.*		
1867	211, 956	$12, 435	....	$5, 945	$18, 380
1868	211, 428	12, 682	....	22, 484	35, 166
1869	302, 735	27, 840	51, 973	1, 644	29, 484
1870	222, 658	20, 907	49, 689	1, 544	22, 451
1871	325, 153	40, 070	76, 688	2, 680	42, 750
1872	359, 797	65, 264	....	5, 763	71, 027
1873	512, 094	45, 679	687, 101	10, 182	55, 861
1874	588, 381	37, 760	140, 120	4, 416	42, 176
1875	411, 590	31, 363	96, 165	3, 421	34, 784
1876	540, 340	22, 266	106, 941	5, 165	27, 431
1877	544, 850	21, 115	119, 212	5, 876	26, 991
1878	934, 207	42, 807	100, 233	4, 932	47, 739
1879	452, 910	20, 579	60, 197	2, 950	23, 529
1880	994, 203	46, 870	147, 276	6, 865	53, 735
1881	843, 440	49, 354	143, 003	6, 430	55, 784
1882	995, 029	45, 455	191, 133	8, 323	53, 778
1883	1, 209, 514	47, 107	133, 327	5, 864	52, 971
1884	*a*1, 195, 450	*b*49, 990	(*c*)	16, 727	66, 717

a Chalk, 1,026,200 cwts.; cliffstone, 169,250 cwts.
b Chalk, $34,894; cliffstone, $15,096.
c Not specified.

Whiting imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	8, 168, 123	$40, 879	1876	2, 605, 332	$13, 270
1868	5, 530, 042	19, 390	1877	2, 390, 333	11, 270
1869	3, 438, 396	17, 289	1878	1, 871. 374	7, 903
1870	5, 650, 728	27, 293	1879	1, 365, 867	5, 977
1871	5, 219, 396	24, 710	1880	1, 803, 577	7, 503
1872	6, 392, 717	31, 464	1881	1, 974, 913	7, 806
1873	6, 197, 017	32, 622	1882	1, 722, 711	6, 676
1874	3, 749, 122	24, 734	1883	2, 216, 018	8, 396
1875	4, 170, 569	22, 492	1884	3, 910, 829	15, 189

Paris white, ground in oil, imported and entered for consumption in the United States.

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1872	596, 762	$3, 279	1874	51, 939	$559
1873	10, 502	486	1875	22, 627	1, 132

Exports of chalk.

Fiscal years ending June 30—	Unmanufactured.	Manufactured.	Total.
1870	$1, 695		$1, 695
1875		$1, 594	1, 594
1876		440	440
1878	69		69
1880	301	664	965
1881	108	958	1, 066
1882	210	1, 131	1, 341
1883	199	1, 943	2, 142
1884	236	1, 890	2, 126

FELDSPAR.

By David T. Day.

Occurrence.—Although the different varieties of feldspar occur very widely distributed, as constituents of many crystalline rocks (granite, syenite, felsite, gneiss, etc.), the occurrence becomes quite limited when only those deposits are considered which are applicable to industrial purposes. For among the feldspars orthoclase alone has a commercial value, and this can only be used where it is found in large masses tolerably free from other minerals. In the United States, Maine, Massachusetts, Connecticut, New York, Delaware, Pennsylvania, Maryland, and Michigan have furnished orthoclase for use in pottery. In Maine the feldspar quarries at Edgecombe, Lincoln county, and Brunswick, Cumberland county, contributed to the supply for 1883 and 1884. Feldspar is also found in many deposits, some of which are quite extensive, near Brunswick. It is found at Topsham, Sagadahoc county, and at Georgetown, Lincoln county, Maine. In Massachusetts a deposit is mined in the southwestern part of the town of Chester. In New York there are quarries at Fort Ann, Washington county, and at Tarrytown, Westchester county. Connecticut furnishes a large part of the total supply from deposits at South Glastonbury, Hartford county, and Middletown, Middlesex county. In Pennsylvania an important deposit is worked at Brandywine Summit, Delaware county. The deposit extends northeast and southwest in the form of a vein about 60 feet deep and 50 feet wide. In Delaware a very pure variety of feldspar is found, and mined, at Tucker's quarry and Hokessin pits, New Castle county. While the amount mined in this locality is small, it is of exceptional purity. These sources combine in furnishing feldspar to all the potteries in the East, and so far as can be ascertained no feldspar is mined anywhere else except near Humboldt, Marquette county, Michigan, where operations have lately been commenced.

Amount mined.—In 1883 the total output for the United States was 14,100 long tons. In 1884 the output was reduced to 10,900 long tons. The following table shows the production for the several States in which it was mined:

Feldspar mined in the United States in 1883 *and* 1884.

States.	1883.	1884.
	Long tons.	*Long tons.*
Maine	3, 200	900
Connecticut	6, 000	6, 000
Massachusetts	500	500
New York	500	500
Delaware	900	1, 000
Pennsylvania	13, 000	2, 000
Total	14, 100	10, 900

Value.—A small amount of very pure feldspar mined at Hokessin, Delaware, is used for making artificial teeth; it has a spot value of $40 per ton. Thirty-five tons of such feldspar were mined in 1883 and 1884. The ordinary grade of feldspar is worth $5 per long ton delivered on board vessels in the condition in which it is taken from the ground; when pulverized it is worth from $10 to $12 per short ton. This would make the value of the total supply for 1883, $71,112; and for 1884, $55,112.

Importations.—Small amounts of feldspar are imported, as will be seen by the following table:

Feldspar imported and entered for consumption in the United States, 1869 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1869	$551	1877	$10
1872	19	1882	82
1874	94	1883	....
1875	219	1884	1,409
1876	11		

Utilization.—The use of feldspar in pottery depends upon the fact that it will fuse at a very high temperature. The best porcelain consists of a mixture of infusible clay and feldspar; by subjecting this to very powerful heat the feldspar fuses and forms a cement for the clay. When feldspar is used in this way it is said to form a part of the "body" of the ware. The amount of feldspar so mixed with the body of porcelain is only sufficient to hold the clay firmly together. The mass is porous and requires a smooth coating of some fusible substance called a "glaze." The best substance for such a glaze is feldspar, because it forms a smooth surface which is very hard and resists the action of all substances exceedingly well. It is used as the glaze for the best kinds of porcelain, such as that made at Sèvres. It would be used generally except for the high temperature necessary for its fusion, and there are many other kinds of glaze which will fuse more readily. Feldspar is used in less quantity than any other constituent of pottery, particularly in this country, and the proportion varies according to the exact nature of the clay employed. The proportion used by each manufacturer depends upon some recipe which he has found most suitable for the temperature and other conditions under which he works. Besides the use in porcelain manufacture, feldspar is also used in more common grades of pottery, and here also a manufacturer always clings to some arbitrary proportion which he has found valuable. With the present increasing tendency to manufacture better grades of pottery, as shown by the new kinds of porcelain made at Trenton, Baltimore, and Cincinnati, and the use of higher temperatures in these potteries, it seems probable that the consumption of feldspar will increase markedly within the next few years.

LITHOGRAPHIC STONE.

Lithographic stone is found in the following localities in the United States: Talladega county, Alabama; Kern county, California; Illinois; Anamosa, Jones county, and Van Buren county, Iowa; near Elizabethton, Hardin county, Estill, Kenton, Clinton, Rowan, and Wayne counties, Kentucky; Saverton, Ralls county, Missouri; Clay and Overton counties, Tennessee; Llano county, Texas.

As was stated in "Mineral Resources, 1882," page 595, lithographic stone is not as yet quarried to any considerable extent in the United States, although stone of inferior quality is found in many localities. The points in which the American stones fail in satisfying the requirements of the lithographer's art are there fully stated. Generally speaking this inferiority is due to one or more of the following characteristics: The stones are harder, heavier, more siliceous, and consequently more brittle, coarser-grained or less uniform in texture than the stone from Solenhofen. The fact too that few, if any, American stones have been found in layers, but require to be sawed into slabs of the requisite thickness, is a serious drawback. Much of it is seamed with quartz veins or stained with iron. It should be added that small samples from several localities have been tested and found equal in most, if not all, respects to the Bavarian stone, and with deeper quarrying it is quite possible and even probable, that merchantable quantities of excellent quality may be discovered. In spite of the inferior quality of the American stone there would probably be a large demand for it for cheap work, transfers, etc., were it not for the difficulty experienced in obtaining it in large slabs, owing to its want of cleavage. As it is, there is very little of it on the market.

The supply of lithographic stones at Solenhofen continues to decrease, and the price to increase. At present it is very difficult to obtain any of the best quality of the blue-gray stone here, as it is monopolized in Europe. The prices in 1884 were as follows: For blue-gray, double-faced stone, 6 to 24 cents per pound; for yellow stones, double-faced, 1½ to 12 cents per pound; the price varying with the size of the slab and the quality of the stone.

With the decreasing yield of the Solenhofen quarries, and the constantly increasing demand for the stone, it becomes more and more certain that the American stone will be brought into the market, or that some substitute for lithographic stone will be discovered or invented. Already zinc plates are in use for the commoner grades of work, while an artificial deposit of carbonate of lime upon zinc plates is being introduced. It is very possible that the latter may supersede lithographic stone entirely.

The imports of unengraved lithographic stone during late years have been as follows:

Lithographic stone imported and entered for consumption in the United States, 1868 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1868	$13, 258	1877	$44, 503
1869	17, 044	1878	42, 709
1870	14, 225	1879	37, 746
1871	21, 311	1880	56, 310
1872	36, 146	1881	77, 894
1873	44, 937	1882	111, 925
1874	36, 902	1883	104, 313
1875	41, 963	1884	128, 042
1876	47, 101		

ASPHALTUM.

Occurrence.—Asphaltum is produced in the United States in merchantable quantity in California only, though occurrences are reported in various other parts of the country. The principal localities of occurrence in California are described in detail by Professor Hilgard in an accompanying paper. It is reported also in West Virginia and in western Colorado. For many years most of the asphaltum consumed in California was obtained from the deposit near Carpenteria. In this locality the deposit is very heavy, and is situated immediately on the ocean beach, convenient to a shipping point, but, as the mineral is rather impure, and as most of it has become indurated through the escape of the more volatile portion, thus causing trouble in breaking it out, other beds have come to be worked more extensively, while work upon this has decreased. At the Rancho La Brea, 7 miles west of the town of Los Angeles, the deposits cover a large area. Most of the asphaltum here, as at Carpenteria, is of so low grade that it has to be melted and sepated from its impurities before it can be used. That obtained in Santa Barbara county, as well as that at the Corral de Piedra and at Sargent's ranch, is of better quality, though at the latter locality the deposit is not very extensive. The deposit at Sulphur mountain covers many acres, with a depth varying from 5 to 20 feet, and the deposit is in a constant state of enlargement.

The consumption of asphaltum in California is at the rate of 2,500 short tons a year, an amount which represents very nearly the quantity taken from the beds, very little being exported from the State, that little being to British Columbia, Oregon, and Nevada. The total is perhaps 3,000 tons. The price of crude asphaltum in San Francisco ranges from $9.50 to $13 a ton.

Foreign sources.—All the asphaltum used in the East is imported, mainly from the island of Trinidad, on the coast of Venezuela. A smaller, but still considerable, amount is imported from the Val de Travers, Neuchâtel, Switzerland, and a small amount from Cuba and Germany. The Trinidad deposit, known as the "Pitch lake," occupies a small depression on the highest part of the island, and covers about 100 acres. Near the margin the asphaltum is solid, or nearly so, grading off to a viscous liquid in the center, where it reaches a temperature of several hundred degrees centigrade. The crude Trinidad asphaltum contains from 30 to 33 per cent. of water, the remainder being made up of 52 per cent. bitumen and 48 per cent. of earthy matter. The cost of crude Trinidad asphaltum in New York in 1883 and 1884, was $11.50 a ton, and of refined asphaltum, $23.50.

The deposit at Val de Travers, Switzerland, known as asphalt rock, consists of limestone uniformly impregnated with bitumen. The price of this material, ground and ready for use in New York, is $18 a ton; and asphalt mastic, which is asphalt rock with an addition of refined bitumen, costs $22 a ton.

Asphaltum imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	....	6, 268	1876	1, 613, 090	23, 818
1868	369, 368	5, 632	1877	9, 063, 771	36, 550
1869	405, 410	10, 559	1878	10, 952, 515	35, 932
1870	976, 818	13, 072	1879	16, 167, 142	39, 635
1871	2, 602, 759	14, 760	1880	33, 659, 802	87, 889
1872	2, 948, 451	35, 533	1881	25, 765, 530	95, 410
1873	4, 627, 235	38, 298	1882	30, 030, 437	102, 698
1874	2, 366, 295	17, 710	1883	66, 231, 425	149, 999
1875	2, 351, 855	26, 006	1884	72, 076, 408	145, 571

Uses.—Asphalt in its various forms is used for a great variety of purposes. The principal among these, however, are paving of streets and sidewalks, floors, walls, and roofs of buildings, and for lining cisterns, pipes, etc. Its use for pavements is increasing at a very rapid rate. For this purpose Trinidad asphaltum, after being refined, is mixed with crude petroleum oil in the proportion of 100 parts of asphaltum to 5 or 20 of oil, giving what is commonly known as asphaltic cement. Of this 12 to 15 parts are mixed hot with 83 to 80 parts of fine sand and from 15 to 5 parts of powdered carbonate of lime. Upon a foundation formed of cement, mortar, or concrete this mixture is laid in two coats. The first contains a higher proportion of asphaltic cement than the second or surface coat, which is put on at a considerable temperature, and, after being dusted over with hydraulic cement, the whole is rolled with heavy steam rollers. The Neuchâtel pavement is made simply of the ground Neuchâtel rock, laid hot upon a foundation of concrete or other similar material and rolled with steam rollers. Asphaltic mastic is used for floors and roofs of fireproof buildings, etc., as it is more lasting than simple asphalt rock.

THE ASPHALTUM DEPOSITS OF CALIFORNIA.

BY E. W. HILGARD. (*a*)

The petroleum-bearing formation of California, presumed to be of Miocene Tertiary age, embraces the main body of the Coast range around and south of San Francisco bay and southward at least to Ana-

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[a] In 1878 the writer, at the request of Mr. Henry Villard, undertook the exploration of the asphaltum deposits of California, with a view to ascertaining their sufficiency and adaptability to certain technical uses then in contemplation. The results obtained in this exploration are now given to the public by permission of Mr. Villard.

heim, Los Angeles county. Northward of the bay the predominant materials of the formation are clay shales or siliceous shales. Within the petroleum region sands more or less consolidated, alternating with ledges of calcareous sandstone and claystone, prevail. Indications of bitumen are reported to have been found as far north as Cape Mendocino. It has been reached by the auger near San Pablo, Alameda county, and more abundantly in Santa Clara county, southward of San José. Thence southward the indications of bituminous deposits continue, mainly in the landward portion of the Coast range, so that oil in more or less satisfactory quantities has been obtained at numerous localities along the western border of the San Joaquin valley. It is not, however, until we approach the latitude of Santa Barbara county that the petroleum-bearing strata are found above the ordinary level of the country, when by the oozing out and partial evaporation of the oil they give rise to easily accessible deposits of asphaltum. From the Cayamas river southward the bituminous beds often appear on the seashore, and petroleum springs even indicate their position off shore at several points.

While the process of subaërial evaporation, however, produces the arger and more striking portion of the asphaltum beds, the mineral occurs also under other conditions, pointing to distillation by subterranean heat as the chief factor in the process of consolidation. Sometimes, again, the two modes of formation are combined so as to render it difficult to define the exact limits within which each of the two has acted, although ordinarily even hand specimens bear the unmistakable evidence of their origin.

The practically important asphalt deposits of California lie within the counties of Santa Barbara, Ventura, and Los Angeles. The first and last named furnish alone thus far the commercial supply; but it is in Ventura that the oil-bearing formations, as well as the processes active within them, can best be studied, and this part of the region will therefore be first considered.

Ventura county.—This county is traversed almost centrally, from northeast to southwest, by the Santa Clara river, which heads in the San Fernando and San Gabriel ranges, on the southwestern border of the Mojave desert. Not far from where the river emerges into the open country, on the line of the Southern Pacific railroad, lie the productive oil wells of Newhall, which have long supplied a considerable proportion of the consumption of mineral oils on the Pacific coast. Only a few miles away from this locality a small surface deposit of black asphalt appears at an elevation probably a thousand feet above the valley. Lower down we come to the well known flowing well of Sespe, located in a small side valley to the northward, and bored to the depth of several hundred feet; and here again we hear of asphalt deposits "away up the hills." Since in this region the strata are not greatly disturbed, it appears that there are at least two petroleum-bearing levels, a thousand feet or more apart, of which the lower seems throughout to be the more prolific in oil, while the upper one is the source of innumerable local outflows, usually of thick, blackish-green oil, which upon exposure to the hot sun of the region gradually hardens into solid asphaltum.

Next below the valley of Sespe, that of Santa Paula comes into the main valley from the northward. It forms the eastern limit of the mountain mass known as the Sierra del Azufre, or Sulphur mountain, also now commonly called the "Petroleum range," which abuts on the sea beach near the town of San Buenaventura, making a length of 16 miles; while the average width between the main Santa Clara valley and that of Ojai on the north is about 7 miles. This range forms the connecting link between the Santa Inez mountains, reaching in from Santa Barbara, and the Sierra San Fernando; and it is the chief region of occurrence of the "brea" in the county. Its rocks, consisting of the usual sands, with intercalated ledges of a cavernous calcareous sandstone, are almost undisturbed, with a slight dip northward into the Ojai valley. Hence, while there are a few patches of "brea" on the southern slope, by far the greater outflow takes place on the northern, acquiring a development which both in kind and *apparent* quantity is unusual and impressive. The thick oil or pitch oozes or flows out at a level several hundred feet above the valleys, in the heads of the ravines, and thus forms surface deposits appearing as walls or terraces along the slopes, or else, most commonly, glacier-like masses moving slowly down the ravines and partly solidifying into rock-like masses on the hillsides or where a break in the surface occurs; partly lying in the huge cakes a foot or two in thickness, on the more level portions; or finally, forming lazy streams in the beds of rivulets that in the wet season carry a regular current of water, but during the dry and warm portion of the year exhibit delusive reflecting surfaces of shining tar, generally mingled with a little calcareous water which serves to delude all kinds of living creatures into the belief that they may there slake their thirst. Thus gophers, moles, squirrels, rabbits, all kinds of birds from the buzzard and hawk to the canary, as well as all kinds of insects, are continually falling victims to this delusion, and may be found just caught or completely submerged, as the case may be, in the pitiless viscid mass, which rarely releases a victim once touched. The frequent occurrence of the bones of lambs and calves on the apparently solid surface proves that these, and sometimes even their elders, are not safe from harm on the treacherous ground. Even mankind sometimes find it difficult to escape the grip of the pitch without at least the loss of boot or shoe. The calcareous water incrusts stems and leaves as it descends; and in places exposed to warm sunshine its rapid flow contrasts oddly with the slow, ropy motion of the black tar, sometimes arrested in mid air by a fall of temperature, until the next day's sun starts it again on its slow journey to the valley level. There it sometimes accumulates in masses several acres in extent, and at some points as much as 15 feet in thickness. It need hardly be explained, however, that these masses are far from being pure, having in their descent picked up every movable object, from sandstone bowlders to small gravel and sand, sticks and leaves, small tree trunks and fragments of larger ones, as well as, invariably, a miscellaneous collection of animal bones in great variety. The popular estimate of the amount of material to be found in these localities is, moreover, greatly exaggerated by the large surfaces that on the mountain sides are often covered only with a thin sheet of the hardened pitch, yet appear like solid masses of available asphalt. These circumstances, and the extreme irregularity of the scattered deposits, render it extremely difficult to make any close estimate of the amount of actually available material. According to the best information I have, about ten acres of ground, covered to the depth of from 2 to 3 feet with the crude mass, lie within 8 miles of San Buenaventura landing. Thence up the lower Ojai valley nearly every ravine for 8 miles affords a larger or smaller deposit of similar material, representing in the aggregate a very large supply.

At a point about 16 miles from the seashore there is quite a sudden ascent of some 500 feet from the lower to the upper Ojai valley, and here the level from which the tar flows is reached. Terraces of asphalt appear at a certain level on every hillside, generally originating in a more or less copious spring which may or may not still be flowing—in many cases doubtless obstructed by its own products. At one place there is in a cultivated field a caldron about 10 feet in diameter, filled with bubbling tar and water; the bubbles consisting of carbureted hydrogen. From this spring a stream of tar has flowed in the bed of a creek for some 600 yards, creeping along lazily under the sunshine by day, resting at night, and occasionally forming a sluggish cascade of stringy tar over some ledge or break in the ground. From the semifluid tar to the hard but somewhat cellular asphalt there is every shade of transition in these deposits of the upper Ojai; and I estimate that within the Rancho Viejo, on the Ojai side of the divide, the deposits covered about six acres of ground, the average thickness being not less than 2 and perhaps as much as 4 feet.

From the eastern end of these deposits the drainage is toward the Santa Paula valley, and here, flanking the valley of Seesaw creek, is the largest of the deposits in the region. For quite half a mile the southern mountain side bears huge terraces of black ashpalt, over which the black oil and tar ooze in constant streams, some of them overflowing the roadway so as to submerge the felloes of the wheels; at one point the latter run on a natural asphalt pavement for about 30 yards. The quantity of material here must be estimated by the 100,000 tons, and certainly not less than a million tons occur within the three miles between this place and the ascent from the lower Ojai valley. The country rock being mostly a brittle clay shale, its fragments are often plentifully mixed with the asphalt; but abundance of measurably pure material could be selected, and the impure portions would serve as fuel for the eliquating process of purification.

Near these heavy deposits the oil-bearing stratum appears to cross over to the north side of the valley, for as we descend eastward the glacier-like masses of "brea" lie in the ravines on the northern side, and another bubbling caldron of black tar and water occurs close to the road. A well bored close to it flows thick oil at the rate of about six barrels per day. Similar wells have been sunk at several points in the Ojai valley, generally to the depth of between 200 and 300 feet, but none of them have yielded paying quantities of oil. The best yields and the lightest oils have been obtained in wells sunk on the plateau of the "Sulphur mountain," evidently into the stratum that furnishes the ooze toward the Ojai and Seesaw valleys.

The largest deposit on the Seesaw is about 20 miles from San Buenaventura via the Ojai valley, and about 6 miles from Santa Paula in the main Santa Clara valley, whence the distance to the coast is 16 miles.

The retort assay of representative specimens from two localities gave the following results:

Assays of asphalt from upper Ojai and Seesaw cañon terraces.

	No. 1. Upper Ojai, Rancho Viejo.	No. 2. Seesaw cañon terraces.
	Per cent.	*Per cent.*
Volatile matter	35.8	39.0
Carbon	28.2	21.0
Ash (gravel, débris, etc	36.0	40.0
	100.0	100.0

No. 1 is a hard vesicular asphalt from hillside deposits on the Rancho Viejo, upper Ojai valley. Scarcely softening in the sunshine; fracture partly dull, partly lustrous; sometimes drops of tar in cavities. Melts fully, and requires a high temperature to drive off the oil, which is thickish. Coke hard, difficult to burn. Supposed average of about 6 acres covered by scattered deposits.

No. 2 is a hard vesicular asphalt from terraces on mountain sides in Seesaw cañon, near the Ojai divide. In heating, behaves much like No. 1; in the ash there are many visible fragments of clay shale.

It is obvious that the material from either locality would answer well for all the ordinary uses of asphalt without further treatment. Better means of transportation would, however, be needed to enable them to compete in commerce with more favored localities presently to be noticed.

Los Angeles county.—Of the asphaltum deposits of Los Angeles county the most noted, and the one thus far mainly worked, is that located on the Rancho de la Brea, 7 miles west from the city of Los Angeles and 9 miles from Santa Monica landing, but within 2½ miles of the Santa

Monica branch of the Southern Pacific railroad. This ranch forms part of the undulating mesa land lying at the southern foot of the Sierra Santa Monica, and at this point elevated probably about 350 feet above the sea. "Outcrops" of asphaltum extend here over an area of about 80 acres, forming the main body of a low ridge. On this area there are numerous springs and small basins from which tar, water, and gas flow more or less constantly, and around each of these outflows a mushroom-shaped mass of solid asphalt has accumulated, which is frequently continued into radial fissures in the soil. The smaller masses of this kind are called "chimneys," and often yield tons of the purest mass, such as that represented by assay No. 3, below.

There are, however, three large bodies of asphalt, evidently filling deep basins originally constituting tar lakes, but now solidified by the evaporation of the lighter oils. The mineral is therefore hardest on the surface and becomes softer as the depth increases. Sometimes the body shows no visible impurities for several yards, but more generally more or less fragments of the country rock (a soft shaly sandstone), gravel, and an extraordinary number of animal bones, are mixed in. At some points are found masses of regular bone conglomerate cemented by asphalt; at others, and especially in the most northerly of the three bodies, there is a hard material of rough, gritty fracture, an asphaltic sandstone ("rock asphalt;" see assay No. 4). This, as well as the hard surface material referred to, is not used for refining, as both require too high a heat for eliquation.

At the time of my visit only the largest and most southerly of the three bodies was being worked. The "old pit" within this mass was about 100 by 300 feet in area and 30 feet in maximum depth, but the lower limit of the deposit had nowhere been reached. Moreover, the largest portion of the unavailable matter—rock, gravel, and asphaltum conglomerate too poor for refining—had been dumped in the pit itself, and the extraction being carried on by gangs of Chinamen in the most primitive manner the working face was largely covered by the refuse dump, which had evidently been moved back and forth a number of times, and made such wild disorder that it was not easy to gain a definite idea of the nature of the walls. The foreman estimated that an average of about 50 per cent. of the crude material mined was obtained in the shape of "refined" mass, but the analysis of the latter given below (No. 6) shows how imperfect was the process of eliquation. The latter was performed in large cast-iron pans, about 8 feet long by 3 feet wide and 2 feet deep, set in rough stonework, and heated by means of the refuse mass. The crude material is piled in and the melted asphalt gradually collects as a purer layer between the "settlings" and "skimmings," the latter being the lighter gravel, small bones, etc., which collect on the surface and are skimmed off, after which the molten mass is ladled out into rough molds which form it into bricks ranging in weight from 50 pounds upwards. The Chinamen were paid $3 per ton of refined product. So far as ascertainable, about 15,000 tons of such "refined" asphalt had been taken from the "old pit" up to that time. From surface indications I estimate that this main body extends over a surface of not less than 8 acres. The downward limit has nowhere been reached. About 150 yards to the westward of this main basin there is another, covering apparently about 2 acres of ground. This has been dug into to a depth of about 15 feet; it consists largely of "rock asphalt" (No. 4), with occasional "chimneys" of very pure mass.

About the same distance to the northward of the main basin is another, covering about 5 acres, so far as visible. Here the surface material is so hard that it has been blasted and used as fuel in distilleries at Los Angeles. It becomes softer as the depth increases, but had not been penetrated to more than 6 feet in depth. In one of the pits on this bed a spring of water was struck.

It may safely be estimated that about 15 acres are here covered to a minimum depth of 30 feet with asphaltic materials which have evidently welled up from below, filling fissures and depressions and permeating whatever material came in the way of the fluid mass, and forming attrition-conglomerates of all kinds and degrees of fineness, besides swallowing up, while in the liquid or viscid condition, a large number and variety of animals whose bones abound everywhere.

Small beds of asphaltum exist two miles to the eastward of this locality, underlaid by a sandstone ledge dipping 30° due west. The dips, however, are very variable in the region.

Assays of the several materials resulted as follows:

Assays of asphalts from Brea rancho, Los Angeles county.

	No. 3, purest natural.	No. 4, rock.	No. 5, hard surface.	No. 6, refined.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Volatile matter	71.4	29.6	40.1	41.5
Carbon	14.4	18.4	23.0	16.9
Ash	14.2	52.0	36.9	41.6
	100.0	100.0	100.0	100.0

No. 3 is "mass" from a fissure vein near a chimney; it had been sacked and, having been exposed to sunshine, had run together. Brittle, with lustrous conchoidal fracture; fuses easily, and has to be heated very carefully in order not to froth over. Coke light and easily burned.

No. 4 is rock asphalt from the mass westward of the "old pit," taken from about 3 feet depth. Fuses completely, but at a much higher temperature than No. 3, and distills off oil at a high temperature only. Very hard, and of rough, dull conchoidal fracture.

No. 5 is hard asphalt, scarcely softening in the sun; fracture partly dull, partly lustrous, more or less vesicular, the cavities sometimes filled partly with fluid tar and lower down with water. Fuses fully at a high temperature, and requires high heat to drive off the oils. Coke hard, vesicular, difficult to burn.

No. 6 is refined asphalt, from material taken chiefly at or near the bottom of the "old pit," 30 feet below surface. Raw material much mixed with bones, but resinous-lustrous on the fracture. Melts readily, flows very thinly, and gives off oils readily at a low temperature.

There is in this county, near Anaheim, at least one other, but much smaller, deposit of asphalt, which was personally visited. It occurs in a cañon, and is probably of the glacier-like character so strongly developed in Ventura county. It has been used in making gas at Los Angeles City. Other deposits are reported, but are probably of small extent and importance compared with that at the Brea rancho.

Santa Barbara county.—In this county the indications of the presence of bituminous deposits are widespread, especially in the eastern portion; and doubtless the earliest report indicating their existence on the Pacific coast comes from the early navigators who passed through the "petroleum sea" in the Santa Barbara channel. The striking appearance of the water, covered with myriads of rainbow spots or unbroken sheets of color extending scores of yards and sometimes continued for 15 or 20 miles, could not fail to attract the attention of the most casual observer, and was naturally interpreted as promising enormous quantities of oil as the reward of the enterprising searcher. The result of borings has not however corresponded to these high expectations, and the cause both of the alluring promise and of the relative failure becomes obvious on an examination of the oil-bearing formation of the region, which can be best seen on the beach near Carpenteria, about 13 miles east from the town of Santa Barbara; more especially at a point called Las Breitas in consequence of the occurrence of "brea" (bitumen). There is here a bluff bank rising about 20 feet above high tide; the upper part consists, below the soil, of soft shale and sandy material, while the lower 8 feet exhibit a stratum of moderately fine sharp sand, completely soaked with black tarry oil. The material is somewhat friable and is easily quarried with the pick; but it resists the waves like so much rock, and shoals of it appear to seaward for some distance out, causing breakers. The outcrop is traceable for a third of a mile along the beach, and its minimum thickness is seen at low tide to be 12 feet. How far inland it extends is not known; but the presumption must be that, as a member of the Tertiary in an almost undisturbed region, the stratum underlies the coast hills about two miles inland. It is scarcely doubtful that it is the source from which the oil films of the "petroleum sea" are derived, partly through the direct though gradual expulsion of the oil from the sandy matrix by the superior capillary force of the sea water, partly from oil springs which are seen to rise from shallow depths in the channel between the mainland and Santa Rosa and Santa Cruz islands.

The petroleum-soaked sand has in times past been distilled for oil and tar, but after the discovery of more ample supplies from bored wells this has been abandoned as unprofitable. The assay given below of an average sample from this locality readily explains this abandonment:

Assay of oil-bearing sand from Las Breitas.

	No. 7, oil-bearing sand, Las Breitas.
	Per cent.
Volatile matter	13.3
Carbon	.5
Ash (sand)	86.2
	100.0

It will be noted that nearly the whole of the tarry matter is volatile; the resulting oil is very liquid and light colored.

Occasional signs of bituminous beds are seen on the beach toward Santa Barbara and wells have been bored for oil at several points, but with only limited success as to quality; the oil evidently simply oozing in from sandy materials like those on Carpenteria beach. No asphaltum deposit of any importance, however, is found eastward of the town of Santa Barbara, nor westward until 6 miles away, the Rancho de Las Galetas is reached, on a low plateau which falls off steeply into the sea. Here a black mass of asphaltum, more or less mixed with sharp sand, forms what appears to be a genuine fissure vein or dyke, in the face of a bluff bank about 50 feet high, the foot of which is washed by the surf. The mass is about 30 feet in average thickness, and appears to dip eastward at an angle varying from 40° to less than 30°, or more probably at a somewhat steeper angle, 15° to 20° north of east. At the top of the bank, beneath the soil stratum, it measures only about 25 feet across, but increases to 35 feet at the water's edge. There it runs out for some distance into the sea as a rocky ledge, much of which has been quarried away, but which evidently would have resisted the surf indefinitely. Eastward the bed seems to continue somewhat irregularly, almost horizontally along the beach, for some 600 feet from the westward outcrop. It is stated that in winter, when the quarrying is chiefly done, and southern storms have swept away the sandy beach, the solid material may be seen to form the sea-bottom for some distance out, and most of what is shipped is preferably quarried from these lower levels at low tide. What appears to be the landward continuation of the bed has been struck by the plow about half a mile inland. But supposing the deposit to continue in that direction only for the same distance to which it is seen on the beach (300 feet), and that its average thickness is 30 feet, some 140,000 tons of the material may be considered to be in sight.

Small fissure veins, mostly composed of purer, and sometimes of nearly pure, shining substance, run out from the main mass at numerous points, and are visible in the face of the bluff for some distance beyond the 600-foot limit assumed above. Moreover, it is stated that the year before the caving away of a bank about half a mile below the great bed disclosed a "pocket" of very good asphalt, from which some 40 tons were shipped. On the whole, therefore, the probabilities that a very large supply can be obtained in this vicinity are very great.

The character of the main mass here is, on the whole, most nearly like that of the "rock asphalt" from the Brea ranch, described above, only the asphaltum is softer and more oily, and yields in distillation a more fluid oil. There is nowhere any appearance of stratification or even segregation into sheets, but it seems as though the whole had been injected from below as an almost uniform, soft, doughy mass, which in places carried with it horses of sandstone, which themselves are often traversed by a network of veinlets carrying pure shining pitch, apparently injected under considerable pressure. The fracture is roughly conchoidal, and the material is quarried with some difficulty by means of wedges and sledges.

The rock overlying the asphaltum is mostly a soft, sandy shale, easily dug away with the pick; the floor stratum is similar. Occasionally there occur in it hard, flinty nodules, which appear to be characteristic of the petroleum-bearing formation of Ventura also.

Assays of the several kinds of material found here gave the following results:

Assays of asphaltum from the Galetas bed.

	No. 8, lower portion.	No. 9, pile on wharf.	No. 10, purest veinlet.
	Per cent.	*Per cent.*	*Per cent.*
Volatile matter	23.1	32.8	40.2
Carbon	6.0	10.4	11.7
Ash (sand)	70.9	56.8	48.1
	100.0	100.0	100.0

It will be observed that the bitumen in these samples contains much less carbon than is the case in those from Ventura, and to a less extent in those of Los Angeles. But while the bituminous ingredient is more fusible and oily, there is in the raw material a larger proportion of "ash." No. 8 is really a bituminous sandstone; it softens but does not melt, the fragments almost retaining their form. No. 9 melts fully, and is esteemed a very good material for roofing, pavements, etc. No. 10 becomes very liquid. The distillate from all is very fluid and volatile.

This locality supplies most of the asphaltum used in San Francisco, and in 1878 1,500 tons were shipped, the price, delivered at the city, ranging from $15 to $20, according to quality. A short wharf enables deep-sea vessels to load close by.

Other deposits of asphaltum are reported as occurring far inland, on the waters of the Santa Maria and Cuyamas rivers, in the northern part of the county, as well as in the adjoining county of San Luis Obispo. These are probably of the same character and origin as those of Ventura; and that the oil-bearing strata occur there also at a high level appears from the fact, lately published in local papers, that Solomon's peak, a prominent mountain of that region, was smoking and apparently threatening to develop into a volcano. The samples of rock obtained from this locality are precisely the same soft sandstone elsewhere seen in connection with the asphalt beds, but burnt brick-red, and in places fritted considerably from exposure to a high heat. The writer was therefore able to reassure the population as to the probabilities of an impending volcanic eruption. Quite a similar case occurs on the coast between San Buenaventura and Santa Barbara, where a high cliff has for years been smoking and steaming, and from the prevailing tawny yellow has been baked to a bright red. The fire, doubtless originating from the annual burning of pastures, has reached the high-level oil-bearing strata, and the combustion thus started has continued for years. As the country is more thickly settled, such cases will doubtless become more frequent.

It will be noted that the mode of occurrence of petroleum and asphalt in the California Tertiary is quite similar to that observed in Louisiana(*a*) and adjacent portions of Texas. There also it is the sandy Tertiary strata immediately overlying the Cretaceous (but decidedly of Oligocene age) that give rise to numerous oozes and springs of tar or petroleum, frequently consolidated by evaporation into asphaltum beds. But in the gulf region not only is the area very much smaller (from the Calcasieu to the Angelina river), but the supply has, in all cases thus far reported, been too small to justify exploitation, as may naturally be expected in view of the very inconsiderable thickness of the formation. The petroleum-bearing Miocene (?) strata of California nevertheless correspond to the Louisiana beds in so far as they are immediately superimposed upon the Cretaceous rocks, in the absence of the Oligocene beds. Being of much greater thickness, the sources of petroleum and asphalt within them are much more copious and lasting; and while their production is rarely as abundant, for the time being, as that from the Palæozoic beds of the East, yet the continuous and uniform supply given by the wells that yield at all places the industry upon a much more permanent basis.. The amount of asphaltum in the accumulations described above is a very considerable one—enough to supply the demand of the United States for a number of years, even if no new deposits should be discovered; though the California asphaltum would be at a disadvantage in point of freight charges, in competing with the Trinidad asphaltum in the eastern markets.

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[a] See "Summary of Results of a late Geological Reconnaissance of Louisiana," *American Journal of Science*, November, 1869, page 343. Also, "Supplementary and Final Report" of the same, New Orleans, 1873, page 40.

ALUM.

Native alum, in the form of an efflorescence and as alum-bearing clay and shale, occurs at a number of points in the United States, but has been utilized only to a limited extent. The use of the domestic clays, etc., will depend of course upon the cost of transportation and upon their richness, as compared with imported material. At present, manufacturers rely almost wholly on the latter. Alum clays are found in considerable quantities in New Jersey, and in Indiana, Alabama, Georgia, and other eastern and southern States, some samples reaching 15 to 40 per cent. alumina. Alum occurs at Copperas mountain, near Bainbridge, Ross county, Ohio; in the black shale formation under the Coal Measures, and as alum shale at Alum cove, Sevier county, Tennessee; alum shales are also met with on Copperas branch, 4 miles north of Whitesborough, Grayson county, Texas.

In the Rocky Mountain region small quantities are found at Mount Vernon and in Jefferson county, Colorado, and elsewhere.

It was mentioned in the last report that alum occurred in Silver Mountain district, California, and on Howell mountain, in Napa county, in the same State. Some of the springs at the Geysers in Sonoma county, and at Owen's lake, also carry a small percentage of alum. In addition to these localities alum has been observed at the following localities in California: at the Sulphur Bank, Lake county, in thick incrustations, where also other sulphates occur abundantly; in the placer mining pits in the interior of the State, where it crystallizes on the bed rock laid bare by the hydraulic workings; and near the town of Newhall, Los Angeles county. From an alum-bearing rock near Auburn, Placer county, the exuding mineral is deposited in crystals on the surface. Although no attempt has ever been made to utilize any of these deposits, it is probable that something may in the course of time be done in this direction, as some of them are quite heavy and are favorably situated. In the summer of 1884 a large deposit of native alum was discovered on the Gila river, in Socorro county, New Mexico, about 2 miles below the fork of the Little Gila and 4 miles below the Gila hot springs. The deposit is said to extend over an area 1 mile square, and to be very thick in places. The greater part of the mineral is quite impure, as is usually the case with native occurrences, but it is thought that large quantities are available. The alum-bearing ground has been taken up by a company formed in Socorro. Alum has been found on the Verde river, Arizona, and in various parts of Utah; but at the present price of commercial alum the distance from a market prevents a practical utilization of these deposits. This is also true of the discoveries recently reported from the peninsula of Lower California.

Foreign sources.—Alum is made from alum clay, aluminous earth, and bauxite, which are imported from France, England, and Ireland; and from Greenland cryolite. The imported clays carry from 15 to 70 per cent. alumina, averaging between 45 and 50 per cent. The production of alum clay and shale in the United Kingdom in 1882 and 1883 was as follows:

Production of alum clay and shale in Great Britain.

	1882.		1883.	
	Quantity.	Value.	Quantity.	Value.
	Long tons.		*Long tons.*	
Alum clay	8, 389	£5, 877	13, 478	£10, 108
Alum shale	8, 442	1, 055	8, 288	1, 036

Manufacture.—The principal manufacturers of alum in the United States are: Martin Kalbfleisch's Sons, and G. H. Nichols & Co., New York City; the Pennsylvania Salt Company, Charles Lennig & Co., Harrison Brothers & Co., Powers & Weightman, and the United States Fertilizer Company, Philadelphia; and the Salem Laboratory Company, Boston. The total production of commercial alum in this country during the past three years has been about as follows:

Alum made in the United States in 1882, 1883, *and* 1884.

Years.	Quantity.	Price per pound.	Value.
	Pounds.	*Cents.*	
1882	36, 000, 000	2	$720, 000
1883	35, 000, 000	2⅛	743, 750
1884	38, 000, 000	1⅞	712, 500

Imports.—In addition to the alum clays, etc., imported for the manufacture of commercial alum, and which are free of duty, considerable quantities of alum, "alum substitute," aluminous cake, etc., are also brought to this country. On these latter the duty is 60 cents per 100 pounds. Since 1867 the imports have been as follows:

Alum (classed as alum, alum substitute, aluminous cake, and sulphate of alumina) imported into the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	5, 573, 285	$85, 760	1876	7, 266, 735	$103, 152
1868	3, 110, 095	47, 887	1877	8, 259, 175	112, 275
1869	2, 038, 549	34, 385	1878	8, 645, 248	107, 394
1870	2, 485, 722	39, 669	1879	5, 961, 057	65, 708
1871	4, 712, 840	74, 450	1880	2, 112, 570	23, 435
1872	3, 996, 826	64, 465	1881	2, 086, 950	22, 331
1873	4, 218, 621	66, 243	1882	2, 487, 188	29, 929
1874	4, 053, 588	67, 913	1883	1, 495, 661	21, 126
1875	6, 951, 396	112, 516	1884	1, 461, 041	19, 487

BLUESTONE.

During the last three years the amount of bluestone (sulphate of copper, "blue vitriol") made in the United States has been nearly as follows:

Bluestone made in the United States in 1882, 1883, *and* 1884.

Years.	Quantity.	Average price.	Value.
	Pounds.	*Cents.*	
1882	3, 325, 000	5. 75	$191, 187
1883	5, 344, 000	5	267, 200
1884	4, 224, 000	4. 30	181, 632

Of the production in 1882 about 15 per cent. was obtained from foreign ores and matte; in 1883 and 1884 domestic copper oxide furnished practically the whole supply. The demand for bluestone in pan amalgamation has fallen off latterly, and its principal consumption is in the manufacture of paris green and dyes, and in telegraphy for galvanic batteries.

As will be seen from the following table, the present duty on bluestone, 3 cents per pound, is virtually prohibitory, and the imports for the past few years have been insignificant. No exports of bluestone are recorded.

Sulphate of copper (blue vitriol or bluestone) imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	1, 971, 902	$118, 166	1876	4, 129	$247
1868	726, 452	44, 469	1877	190, 657	10, 283
1869	917, 818	48, 377	1878	65, 400	3, 433
1870	53, 553	2, 793	1879	2, 552	123
1871	45, 809	2, 340	1880	2, 750	141
1872	74, 693	4, 575	1881	20	4
1873	79, 466	4, 726	1882	20	3
1874	14, 598	1, 015	1883	536	28
1875	77, 215	6, 657	1884	10	1

COPPERAS.

Sources.—Almost all the copperas (sulphate of iron) now produced in the United States is made as a by-product in wire works, galvanizing works, and rolling mills, and in the treatment of scrap tin plate. The sulphuric acid used in such works is utilized as long as possible as a cleaning agent, and the waste acid is then neutralized by adding scrap iron, the iron solution being boiled down until crystals of copperas are formed. None is now made in this country by leaching sulphate-bearing clays. Only one establishment, the Steubenville Copperas Works, is now engaged in making copperas by oxidizing pyrites, this works being favored by the accessibility of pure pyrites and cheap fuel, and selling its product at rather better rates than those commanded by the copperas made as a by-product in wire works, etc. Other pyrites-using works in the neighborhood were, however, obliged to close down.

Copperas is frequently found native, as an impregnation or efflorescence resulting from the weathering of pyrites, often forming deposits analogous to the alum clays. In the far West the occurrences are numerous, but they cannot be utilized at the present price of artificial copperas and under existing transportation rates. A considerable deposit occurs in Santa Cruz county, California, near the town of Santa Cruz.

Production.—During the last three years the amount of copperas made in the United States has been nearly as follows, the estimates being based on very complete returns:

Production of copperas in the United States, 1882, 1883, *and* 1884.

Years.	Quantity.	Average price per 100 pounds.	Value.
	Pounds.	*Cents.*	
1882	15,000,000	75	$112,500
1883	16,500,000	65	107,250
1884	15,500,000	60	93,000

The range in price is very great, depending upon quality and the quantity in which sold. Thus in 1883 sales were made between 50 and 80 cents per hundred pounds, and in 1884 the range was all the way from 37½ to 74 cents per hundredweight, the lower rates being for large lots of impure copperas. A very small amount, used for special purposes requiring great purity, has sold as high as $1 per hundredweight during the last two years. The quantity made has increased very much during the past few years, and prices have steadily declined.

Among the leading makers are: The Cleveland Rolling Mills Company and Grasselli & Co., of Cleveland, Ohio; Harrison Wire Company, of Saint Louis; W. E. Cutter, & Co. (Pillar Copperas Works), of Worcester, Massachusetts; S. P. Wetherill & Co., limited (Crescent Chemical Works), L. R. Krumbhaar, Powers & Weightman, Charles Lennig & Co., limited, Pennsylvania Salt Company, Keystone Chemical Works, and Moro Phillips, of Philadelphia; Gridley & Co. (Phœnix Chemical Works), and Kalbfleisch & Co., of New York City; Craig Brothers, of Chicago; Cooper, Hewitt & Co. (Trenton Iron Company), of Trenton, New Jersey; Howe & Goodwin (Vermont Copperas Company), of Boston; New Haven Wire Company, of New Haven, Connecticut; B. C. Johnston (Steubenville Copperas Works), of Steubenville, Ohio; and many other small manufacturers. The decline in price has had the effect of closing down most of the smaller works making copperas as a principal product, and some of the copperas formed as a by-product in other manufactures is allowed to run to waste, as the cost of recovering small quantities would not permit of a profit.

Uses.—Copperas is used as a mordant in dyeing cotton and woolens, and for conversion to nitrate of iron to be used as a mordant; in making bright iron oxides, Venetian red, Spanish brown, etc., by conversion, for painters' colors; in making Prussian blue; in paper mills, bleacheries, plate-glass works, and chemical manufacturing establishments; in ink manufactories; very largely for sanitary purposes, as a disinfectant; in photography; in the precipitation of gold in leaching works; and to a slight extent in medicine.

Imports.—As will be seen from the accompanying table, small quantities of sulphate of iron are still imported.

Sulphate of iron (copperas) imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

Fiscal years ending June 30—	Quantity.	Value.	Fiscal years ending June 30—	Quantity.	Value.
	Pounds.			*Pounds.*	
1867	2,267,575	$15,096	1876	69,802	$385
1868	181,354	1,062	1877	34,791	230
1869	597,418	3,362	1878	46,875	256
1870	994,850	5,280	1879	87,450	481
1871	1,842,308	9,083	1880	240,258	1,437
1872	637,474	3,899	1881	151,496	956
1873	225,590	1,516	1882	23,517	195
1874	170,511	1,279	1883	38,964	290
1875	138,473	1,171	1884	285,691	1,555

CRYOLITE.

The cryolite found near Pike's peak, El Paso county, Colorado, described by W. Cross and W. F. Hillebrand in the *American Journal of Science*, October, 1883, is of purely mineralogical importance and is noticed here merely because of the frequent inquiries received as to the commercial value of the discovery. This is the only known cryolite locality in the United States. It occurs in small masses as a subordinate constituent of certain quartz and feldspar veins in a country rock of coarse reddish granite. Zircon, astrophyllite, and columbite are the primary associated minerals, the former only being abundant. Alteration products of the cryolite are pachnolite, thomsenolite, prosopite, ralstonite, gearksutite, and fluorite.

The principal source of supply is the Iviktoh deposits in Greenland. The mineral is used in making soda, in the manufacture of a porcelain-like glass, and in Europe it has been utilized to a limited extent in the production of metallic aluminum. There is no duty on imports, and during recent years these have been as follows:

Cryolite imported and entered for consumption in the United States, 1867 *to* 1884 *inclusive.*

[Cwts. are long hundredweights of 112 pounds.]

Fiscal years ending June 30—	Quantity.	Value.
	Cwts.	
1867		$32,876
1868		68,632
1869	182,942	108,303
1870	155,107	105,472
1871	104,140	71,058
1872		75,195
1873		84,226
1874		28,118
1875		70,472
1876		103,530
1877		126,692
1878		105,884
1879		66,042
1880		91,366
1881		103,529
1882	75,160	51,589
1883	130,160	97,400
1884	147,800	106,029

OZOCERITE.

The ozocerite (native paraffine, "mineral wax") deposits occur in and around Soldiers' Park cañon, Utah, in the region where bituminous shales exist. On the south side of the cañon the bituminous shale alternates with gray clay containing mineral oil. In the clay layers are found vertical seams of ozocerite 6 inches to 2 feet thick, distant about 50 feet from each other. The whole formation dips about 35° to the northwest and is observable for thousands of feet. The purest ozocerite from this locality is said to contain 60 per cent. of paraffine wax, 30 per cent. heavy oil, and 10 per cent. residue of coke, which can be utilized as fuel.

Mr. F. Covington, of Salt Lake City, who has been engaged during the past six years in prospecting for ozocerite, in a letter to the *Mining Record*, says: "Mineral wax is found in a sandstone formation in this Territory in veins varying in thickness from a half inch to 15 inches, and can be traced for miles—as also large beds of oil shale in which more or less wax is found. These shale beds vary in thickness from 4 inches to 100 feet, and will ignite with a match. They are within from 4 to 6 miles of the railroad, while the wax veins are within from 100 feet to 2 miles of the Denver and Rio Grande railroad, about 100 miles southeast of Salt Lake City, with plenty of good water and wood in close proximity. I have also found black oil of the consistency of cream, resembling the wax in color and luster; moreover, a kind of black jet of a very high polish. These deposits or veins of mineral wax are about 8,000 feet above sea level, on the divide of the Wahsatch range of mountains, and in Wahsatch county; the country rocks are chiefly sandstone, shale, and clay. The Pleasant Valley coal mines are about 20 miles south of the wax and shale beds." Mr. Covington states that at the close of 1884 there were some 4,000 or 5,000 pounds of ozocerite on sale from this region.

Prof. J. E. Clayton, writing to the *Engineering and Mining Journal*, describes the Utah occurrences as follows: "The paraffine oil shales are found on the east flank of the Wahsatch range, the south flank of the Uintah range, and the west flank of the Colorado portion of the continental divide, or the Rocky Mountain range, especially that portion of it north of Grand river. These beds are probably Miocene Tertiary, and at one time undoubtedly covered the entire area of the great inland sea now known as the sandstone country of Utah, Colorado, Arizona, and New Mexico—a region about 400 miles in length from northwest to southeast, and 200 miles or more in width from northeast to southwest. The Tertiary shales have been swept away from all the central areas of the old basin; but in the higher plateaus along the flanks of the ranges, between the deep cañons, and even to the summit of the Wahsatch range in many places, these Tertiary oil shales are found covering large areas of country.

"A peculiar feature of these oil shales beds is that they are not equally rich in paraffine or wax. In some localities they are very thick, and rich in oil, but poor in paraffine, and the exudations along the flanks of the cañons are simply asphalt, with little or no paraffine. In other localities, the exudations are wax-like and rich in paraffine; but I do not know of any locality where the wax exists in any considerable deposits. In all the localities that I have examined in the Wahsatch range, about the heads of the Spanish Fork cañon, and the heads of Price river (including White river and Fish creek, its principal tributaries), the wax occurs as exudations from the shale beds that have been cut by ravines so as to expose sections of the beds. or where they have been folded by the upheavals, and their edges exposed by denudation. In studying the underlying as well as the overlying beds I find below the richest zone of shales a series of compact beds, in places aggregating in thickness 100 feet or more, that are full of fresh-water fossils, of the usual Tertiary type. The shells in some bands form the major part of the mass. The shaly portion is dark or blackish, in fresh fractures, and contains more or less oil. In some cases, thin splinters of it can be lighted with a match. Overlying these fossil beds is a very fine clay shale with very few fossils in it, varying in thickness from 5 or 6 to 20 feet or more, which is very rich in oil, and, in some localities, rich in paraffine, both as impregnations and in very thin scales and films between the thin laminæ of the shales. This upper bed of oil shale is remarkably tough. Weathered samples assume a grayish or brownish gray color, and divide readily into thin sheets, and will warp in the sun like thin sheets of wood. There seems to be no sand or grit in them. One can saw them as readily as if they were boards. Above this, is a continuation of what appears to be the same close-grained clay shale, of a dove color, many feet in thickness, say from 20 to 40 feet, but containing no oil or paraffine. The oil appears to have penetrated a few feet into this overlying clay shale from below, in some places impregnating it from 10 to 20 feet, while in other places not more than a foot or two. These facts seem to indicate that the oil is of animal origin from the underlying fossil beds above mentioned.

"Why these beds give crude oil and asphalt in some localities, and paraffine oils in other places, is not yet understood. The best paraffine shales yet found are near the rim or outer edge of the old Tertiary lake or sea. Here, large lagoons or lakelets may have been filled with fresh water, and the vegetable slimes and mosses were sufficiently abundant to feed the myriads of mollusca that became periodically entombed in the muddy ooze of the shallow lakes or lagoons that were more or less isolated from the main body of water, thus giving more organic remains of the right sort in some localities than in others. This seems to warrant the suggestion that the local conditions gave an abundant type of organic life of the right kind in some places, while in other localities the vegetable and animal life produced oils almost destitute of paraffine. A careful investigation of the fossiliferous beds underlying the different varieties of oil impregnations would throw some light on the subject. It might possibly reveal the true origin of all the fossil oils, as well as the causes that have produced the different varieties of oil in the same zone of beds, only a few miles apart."

Professor Clayton's opinion of the purity and quantity of the occurrences of ozocerite above described is far less sanguine than many published statements. He says: "No deposits of mineral wax have been found in this old Tertiary basin that equal in richness or purity the ozocerite deposits of Galicia in Austria. Such deposits *may* exist somewhere in this large stretch of the Tertiary beds of the Rocky mountains; but they have not yet been discovered. In the light of our present knowledge, I am inclined to believe that the only way to get the paraffine in large quantity is to distill the shales on a large scale by a similar process to that now used in Scotland. The deposits of wax are small, and scattered over large areas of country. Hence, the collection of the impure varieties of ozocerite found in Utah could not be relied upon to supply any considerable demand. Systematic explorations by boring and otherwise may reveal rich deposits of the mineral; but this requires the employment of special skill and the expenditure of considerable sums of money. All I can say about it now may be summed up in this: That it is a promising field for such explorations; but in my opinion, the distillation of the shales must be finally relied upon for the production of any large supply of paraffine."

Samples of ozocerite of good quality have been obtained from Wyoming, but the deposits have not been developed and their extent is unknown. The recent demand for ozocerite may have the effect of stimulating further exploration. Ozocerite is also reported to have been found lately in the clay fields of Mr. Otto Enst, at South Amboy, New Jersey.

GLASS MATERIALS.

By Joseph D. Weeks.

Constituents of glass.—The essential constituents of glass are silica and one or more metallic oxides. The silica is generally used in the form of sand. The chief oxides are soda, lime, potash, and oxide of lead. Other oxides, as those of zinc, tin, barium, and antimony, are sometimes employed in glass making; and other materials, as manganese, arsenic, and the oxides of tin and copper, are found in glass, but these latter are present either as coloring matter, as impurities, or as materials used to correct impurities.

The silica used in glass making is mixed in the "batch," as the combined materials ready for melting are termed, in the form in which it enters the glass. With the metallic oxides it is different. These are derived from some of the salts of the metals. Soda, for example, is mixed in the batch not as soda but as the carbonate, sulphate, or nitrate of soda, or chloride of sodium; lime and potash usually as the carbonates. Lead, however, is mixed as an oxide, usually as minium or red lead, or sometimes as litharge. In the melting, these carbonates, sulphates, etc., are decomposed, the soda, lime, potash, and lead entering the glass, the other elements of the compounds passing off as gas or in the "glass gall" or "sandiver," as the "scum" on the molten glass is termed. The action of the heat in the furnace, in addition to decomposing the salts of the batch, is to fuse the silica, which acts as an acid, and the soda, lime, and other oxides, which play the part of bases, into silicates. Glass however is not a simple silicate, but is a fused mixture of two or more of the silicates so formed. Sheet or window and plate glass are silicates of lime and soda; lead-flint, of lead and potash; lime-flint, of lime and soda; while green bottle glass is a farrago of silicates of soda, potash, and lime with iron, alumina, etc.

SILICA.

Of glass-making materials silica is the most important, is used in the largest proportion, and is the only one that enters into all varieties of glass. Lead-flint glass contains the least percentage, ranging from 42 to 60 per cent., averaging about 53, and cast plate the highest, some specimens containing as much as 79 per cent., the average being about 74 per cent. Window glass contains about 70 per cent., lime-flint glass 72 per cent., and green bottle glass about 60 per cent.

At the present time sand furnishes most of the silica used in glass making. Fifty years ago the silica for the finer grades of glass was procured by an expensive process of crushing and washing flint and quartz. This process is still used in those districts where good sand cannot be cheaply obtained. Bohemian glass is made almost exclusively from quartz so prepared. Certain siliceous rocks, such as felsite, basalt, and trachyte, containing large percentages of soda and potash, are also used in some parts of Germany and Austria, especially in the manufacture of bottles. The use of these rocks in glass making is a subject worthy of the consideration of American glass makers. These are the exceptions, however. By far the largest portion of the silica of the glass houses of to-day is sand.

The quality of the glass is mainly determined by the quality of the sand used. For the finer grades of glass, especially where freedom from color, perfect transparency, and great brilliancy are essential, only the purest qualities of sand can be employed, as slight impurities, especially small amounts of iron, seriously impair all of these desirable properties. When however color is secondary to cheapness of production, as in the manufacture of green bottles, sands with considerable iron and clay are not only used, but in some cases are preferred, as these materials are fluxes and consequently require less flux in the "batch" or mixture of materials.

Use of manganese as a decolorizer.—The chief impurities in sand are oxide of iron, alumina (generally in the form of clay), loam, gravel, and organic matter. Most of these can be removed by burning and washing, but the iron and part of the organic matter can only be removed or neutralized by the use of chemicals. Burning is necessary where the sand contains much organic matter. For small percentages the heat of the furnace in the melting of glass is sufficient, the carbonized matter being carried away as carbonic acid by the use of arsenic. In washing the sand to remove the clay, gravel, loam, and similar impurities, it is first crushed and pulverized if necessary, and then washed and dried. The sand comes from the drier fine, and almost as white as flour. Of the impurities iron is the most dreaded. It is difficult to remove it or to neutralize its effect, while its presence, even in small amounts, destroys the "color," the limpid whiteness of glass, giving it a greenish tint. Manganese is used to correct this greenish color, but glass so decolorized is liable to acquire a purplish tint or "high color" under the action of sunlight. The only safeguard against this "high color" is the use of sand containing little or no iron, and consequently requiring no "doctoring" of the batch. Sand containing more than 0.5 per cent. of oxide of iron is not considered suitable for any glass, even bottles, while for plate and window glass and the finer grades of table ware the less iron the better.

Use of arsenic as a decarbonizer.—The organic matter when not removed by a preliminary burning decarbonizes in the pot during the melting of the glass materials and is removed by the use of arsenic, which is the great "decarbonizer" in glass making, as manganese is the "decolorizer." The arsenic is added to the batch prior to charging it into the pots.

Tests of sand.—Sand should be perfectly white, not very fine, uniform, even grained, with angular rather than rounded grains. Sand which is very fine, or the grains of which are smooth and rounded, can only be used with difficulty and great uncertainty as to the result. Such sand is liable to settle to the bottom of the "batch," preventing an even mixture of the materials, and producing an uneven glass. Sand should not effervesce or lose color when heated with an acid. Loss of color indicates the presence of clay, loam, or other foreign substance, while effervescence indicates the presence of carbonate of lime. Oxide of iron can be discovered by boiling the sand in hydrofluoric acid and dropping into the solution a few drops of yellow prussiate of potash in solution. The resulting blue color indicates the presence of iron, even in the most minute quantities.

These tests indicate in a general way the value of sand for glass making. An analysis is necessary to give the amount of the impurities. It should, however, be noted that while such an analysis, aided by the appearance and color of the sand, indicates in some measure its purity and value, it is by no means conclusive as to its adaptability for glass making, as a sand of yellowish tint may be purer than one much whiter. Mr. Henry Chance, of Birmingham, England, whose two papers on crown and sheet glass are the best in the language, speaking of color and analysis as indications of purity and value, says: "The sand used by our firm is obtained from Leighton Buzzard, and although of a yellowish tint is more free from iron than many kinds of sand which are white in appearance. The whiteness of sand is a very uncertain test of its purity. Again, two kinds of sand which are shown by analysis to be precisely similar in their composition may produce different results as regards both color and quality of glass." Mr. Chance suggests that this may be due to a difference in the power of the sands, arising from the condition in which the silica exists, to neutralize the bases.

Occurrence of glass sand.—Most of the sand used in glass making occurs as sandstone, is quarried in blocks, and must be crushed and prepared for use. The Fontainebleau (France) sand and some of the Berkshire (Massachusetts) and Juniata (Pennsylvania) sands are of this character. In other cases, while the sand occurs as rock and must be quarried, it rapidly disintegrates on exposure to air and moisture, as at some of the Juniata (Pennsylvania) mines. At other quarries where the formation is saccharoidal, the sand rock has a very weak bond, and is readily detached from place with a pick, rapidly falling into fine sand. This is the nature of the sand at Crystal City, Missouri, and at some of the Berkshire (Massachusetts) mines. While most of the sand used is quarried or mined, some glass is still made, as was the earliest glass, from river or sea sand. This however is only employed for the coarser and cheaper kinds.

Glass sands of the United States.—No better glass sands are found than those of the United States. The French sand quarried at Fontainebleau and the German sands found at Herzogenrath and Hohenbocka, from which most of the best glass of England, France, Belgium, and Germany is made, and the sand from near Mons, Belgium, although of great purity, do not equal some of the American sands. Our deposits of sand suitable for the manufacture of the finest grades of glass are not only extensive but are found at least from Massachusetts to Missouri, perhaps in most of the States. If in the quality of the metal, or in the brilliancy of our glass, we are behind our European competitors, it is not attributable to our sand. These deposits are also in many cases well situated with reference to fuel and transportation. Among the beds most extensively worked are those of Berkshire county, Massachusetts; Juniata county, Pennsylvania; Morgan county, West Virginia; Fox River, Illinois; and Crystal City and Pacific, Missouri. These are all exceedingly pure sands, as the analyses subsequently given will show. Berkshire county furnishes most of the sand for the flint glass made in New England, New York, New Jersey, and eastern Pennsylvania. Some of the flint-glass houses of Philadelphia also procure a portion of their supplies from West Virginia and the Alleghany mountains. The sand for the window and green glass made in New York, as well as part of that used in Ontario, comes from Oswego and Oneida counties; that used for common glass near New York City, as well as in New Jersey and eastern Pennsylvania, is mined in New Jersey from a very extensive deposit that can be traced through the State. This sand is uniform and is often used without washing for the manufacture of window glass. The large quantities of sand required in Pittsburgh, Wheeling, and the factories in their neighborhood come from various points in the Alleghany mountains, mainly from Juniata and Fayette counties, Pennsylvania, and Morgan county, West Virginia. Some is also procured from Missouri. The Fox River sand, found some 60 miles from Chicago, is a very valuable deposit, supplies the plate-glass works at New Albany and Jeffersonville and some of the flint-glass works in the West. It is a beautiful sand, needs no washing, and has given the very best results in use. Some good sand is mined in Indiana. The Crystal City, Missouri, deposit is one of the most important beds in the West, is of great purity, inexhaustible in quantity, and the cost of mining is merely nominal. There is also a deposit of considerable importance at Pacific, Missouri, which seems to be of the same formation as that at Crystal City. The sandstone from this mine is hardened instead of being disintegrated by the action of the air, but water, to a certain extent, breaks the bond. This sand is regularly supplied to the glass works at Cincinnati and many of the works of the West, except those making plate glass. Indeed the extent of the deposits of sand in this country suitable for glass making is almost incalculable. Many of these are not developed, or, if opened, worked only to a limited extent.

The saccharoidal sandstone of Missouri, for example, has been traced for miles through some ten counties, the bed varying from 80 to 133 feet in thickness. At Minneapolis and Saint Paul a rock 175 feet thick is found, furnishing a good quality of glass sand. In many States glass sand has been discovered and reported upon by State geologists and chemists. Of many of these deposits no use has as yet been made. To these reports those desiring information as to the character and extent of the deposits are referred.

In the following table will be found analyses of the most prominent glass sands in Europe and this country.

Analyses of European glass sands.

	France.		England.		Germany.	
	Fontainebleau. (*a*)	Fontainebleau. (*b*)	Leighton Buzzard. (*a*)	Alum Bay. (*b*)	Herzogenrath. (*c*)	Hohenbocka. (*d*)
Silica	99.00	98.80	99.00	97.00	99.240	99.760
Alumina	.50	......	.30	......	.200	.040
Lime	......	......	......	......	.053	.011
Magnesia	......	......	......	......	.033	.012
Manganese	......	......	......	......	......	.015
Sesquioxide of iron	Trace.	......	.50	......	.005	.055
Carbonate of lime	.50	......	.20	......	......	......
Magnesia and sesquioxide of iron	......	.70	......	......	......	......
Water	......	.50	......	1.00	.469	......
Alumina, magnesia, and sesquioxide of iron	......	......	......	2.00	......	......
Phosphorus	......	......	......	......	......	.039
Loss	......	......	......	......	......	.240
	100.00	100.00	100.00	100.00	100.00	100.172

a Authority: H. Chance.
b Authority: Spon.
c Authority: Julius Fahdt.
d Authority: Bischof.

Analyses of glass sands of the United States.

	Massachusetts, Berkshire county.			New Jersey.		Pennsylvania.		Will's Mountain, Cumberland county. (*e*)	Speer, Hancock county, West Virginia. (*c*)	Missouri.	
	Gordon's. (*a*)	Gordon's. (*a*)	Brown's. (*a*)	Downer's, Glassborough. (*b*)	Hilliard's, Maurice river. (*b*)	Speer's, Fayette county. (*c*)	Juniata county. (*d*)			Crystal City. (*f*)	Lincoln county. (*g*)
Silica	99.78	99.61	99.69	98.824	98.850	99.720	98.84	98.35	99.90	99.62	99.55
Alumina	.22	.39	.31	.935	.980	.080	.17	......	......	......	.33
Lime	......			.056	.056	.110	Trace.	......	......	......	.08
Magnesia	......	......	......	.015	.022	.06	Trace.	......	......	......	......
Chlorine	......	......	......	.0054	Trace.	......	......	......	......	......	......
Mauganese	......	......	......	......	......	......	Trace.	......	......	.07	......
Sesquioxide of iron	......	Trace.	Trace.	.165	.130	Trace.	.34	.42	......	......	Trace.
Iron	......	......	......	......	......	......	......	......	......	.09	......
Various	......	......	......	......	......	......	......	......	......	.22	......
Undetermined	......	......	......	......	......	......	......	......	......	......	......
Loss	......	......	......	......	......	.030	.23	......	......	......	......
	100.00	100.00	100.00	100.0004	100.038	100.000	99.58	......	......	100.00	99.96

a Authority: S. Dana Hayes.
b Authority: Professor Cook.
c Authority: Otto Wuth.
d Authority: A. S. McCreath.
e Authority: C. F. Chandler.
f Authority: Crystal City Plate Glass Company.
g Authority: Chauvenet.

SODA.

Until a very recent date all glass would be classed as soda glass; soda, with rare exceptions, being the only base employed by glass makers. The intelligent use of lead and lime are modern inventions, and analysis shows but little potash in ancient glass. Potash and lime were almost always found as impurities in the sodas formerly used and, as a consequence, in the glass made from them, but they were chance materials. There is also evidence that the value and effect of lead was not entirely unknown to the ancient glass manufacturers, but its use may very properly be said to be an English invention of the seventeenth century. Soda for the earliest known glass houses was obtained from the banks of the natron lakes of Egypt; that for modern glass making, until near the beginning of the present century, from the ashes of certain plants, chiefly those of the sea and seashore, such as kelp and the salsodas. As late as sixty years ago English crown and sheet glass was made from the ashes of the kelp of the Scottish and Irish coasts. These ashes contained potash and lime as well as soda and were simply mixed with sand and melted.

Soda ash.—The quality of these vegetable sodas was poor, the quantity limited, the supply uncertain, and the glass made from them variable in character and inferior in quality. Le Blanc's discovery in 1792 of a process of converting common salt into soda ash opened a new era in the glass industry and brought about the most important change that has been made in the chemical part of the maufacture of glass—the substitution of carbonate of soda for the vegetable sodas and subsequently the use of sulphate of soda in place of the carbonate. In the Le Blanc process sulphate of soda or salt cake is first made from common salt and oil of vitriol. This sulphate is then converted into an impure carbonate and the black ash of commerce, by calcination with fine coal and lime, and this by solution and evaporation into the carbonate, the soda ash or British alkali of commerce.

Sulphate of soda.—At first only soda ash was employed in glass making, and it is still used exclusively for some kinds of glass; but it was soon found that there was some advantage in the use of salt cake, and at present considerable window glass is made with the sulphate. Sulphate glass is less liable to devitrify or crystallize in the pot during melting, and hence will carry a larger proportion of lime than carbonate glass. It is therefore harder, takes a better polish, and does not "sweat" as readily.

The use of sulphate of soda demands the introduction of carbon into the "batch." This is supplied by some form of coal rich in carbon, as anthracite, charcoal, or coke.

Manufacture of soda ash in the United States.—But little either of the carbonate or sulphate of soda is made in this country by the Le Blanc process, though the materials for the production of both exist in great abundance. Apart from the fact that the most valuable deposits of the materials necessary to their production are widely separated, the chief obstacle to their manufacture has been that the economical working of this process depends largely on the demand for muriatic acid, which is a by-product of the manufacture of salt cake. This demand is limited in this country, and as a consequence the amount of soda made has been small. The alkali-making districts of England, especially the Lancashire and the Newcastle, supply most of that used in glass making, not only in this country but in most others. In 1884, 287,401,005 pounds of soda ash and 8,416,147 pounds of salt cake were imported into this country.

Ammonia soda.—Until quite recently sulphate and carbonate of soda have been produced only by the Le Blanc process. In 1866 Mr. Ernest Solvay began at Brussels the manufacture of carbonate of soda by a process that has since been called the Solvay or sometimes the ammonia process. This process bids fair to supersede the Le Blanc. The soda ash produced is fully equal to the Le Blanc in quality and can be produced more cheaply. The Solvay soda is 98 to 98½ per cent. pure carbonate, practically free from iron and other impurities, while the Le Blanc soda gives but 78 to 80 per cent. The Solvay soda is also free from the sulphate and chloride which are so productive of "glass gall" in the pot. The manufacture of ammonia soda has been succcessfully established in this country at Geddes, near Syracuse, New York, where some 40 tons a day are made. The first finished ash was made about the middle of January, 1884, since which time the works have been in constant operation, with the exception of a few days' idleness for repairs. Concerning these works and the future of the process the late Prof. B. Silliman said: "This new industry is now actually supplying about 5 per cent. of all the soda ash consumed in this country, and it is destined soon to develop to a very considerable importance, for in western New York are ample beds of pure salt, and probably the same exist in Pennsylvania, while the beds of rock salt lately penetrated in the Wyoming region, New York, and the salt water which flows with the gas in some of the Pennsylvania wells, will provide very large quantities of the raw material for the manufacture of soda ash by the ammonia process. Nor is there need to fear that an adequate supply of ammonia can be obtained, for it must be remembered that every day the coke ovens of western Pennsylvania are wasting far more ammonia than will be wanted, should all the soda ash now used in this country be manufactured here."

In the Solvay process advantage is taken of the chemical reaction which takes place between carbonate of ammonia and salt, in the presence of an excess of carbonic acid. The result is bicarbonate of soda and ammonium chloride. This bicarbonate of soda is washed in proper vessels (after separation from the liquid ammonium chloride in suitable filters) and soda ash produced. The ammonium chloride is regenerated by quicklime and used again in the process. The apparatus used in carrying through this apparently simple process is more complicated than one would suppose, as great care must be taken in dealing with ammonia lest the gas escape and cause great loss. The vessels are of the pattern adopted by Messrs. Solvay & Co. in their European works and are made of wrought or cast iron. The consumption of raw material, etc., varies somewhat from month to month, but the figures given below will approach a fair average:

Capital invested	$600, 000
Hands employed	250
Production per month, long tons	1, 200
Limestone used per month, long tons	2, 400
Coke used per month, long tons	400
Coal used per month, long tons	2, 400
Salt used per month, long tons	2, 400
Barrels used per month	8, 400

Selling price from $1.35 to $1.40 per 100 pounds 48 per cent. equals, say, $35.18 to $37.89 per 2,240 pounds 58 per cent. ash. Imported ash sells at about the same figures. It is said that foreign makers can produce ash much more cheaply than the American. This the Geddes company is forced to admit, but hopes with time and experience to compete with them. During the present year the capacity of the works will be doubled.

Composition of ammonia soda.—Two grades of soda ash are made at Geddes, one carrying 58 per cent. alkali (Na_2O), and a second with 48 per cent. These two kinds are distinguished as "pure soda" for the 58 per cent. and "ammonia soda" for the 48 per cent. The following is an analysis of the "pure soda":

	Per cent.
Iron and aluminum oxides	. 025
Silica	. 025
Carbonate of lime	. 404
Carbonate of magnesia	. 175
Chloride of sodium	. 904
Carbonate of soda	98. 730
	100. 263

The 48 per cent. ash contains about:

	Per cent.
Carbonate of soda	79. 00
Salt	9. 00
Sulphate of soda (salt cake)	9. 00
Silica	1. 00
Lime	1. 00
Iron	1. 00
	100. 00

Ammonia soda in glass making.—Concerning the use of the ammonia soda in glass making, the manufacturers state that owing to its purity its reaction with silica may be too rapid, but that this action may be retarded and time given for the glass to clear by adding about 20 per cent. of common salt, or, as some prefer, adding 10 per cent. of salt cake and 10 per cent. of salt, or only the former. A consumer buying ash having 58 per cent. alkali can add either or both of these ingredients to suit his own taste at less expense than he can purchase them already added in 48 per cent. ash.

The following formula is used in Belgium plate-glass works:

	Parts.
Sand	100
Solvay soda, 58 per cent. alkali	28
Sulphate of soda (salt cake)	3½
Limestone, pulverized	35

All the ingredients thoroughly mixed. This mixture gave 82 per cent. of good glass, against 73 per cent. of glass by the use of salt cake.

It is also claimed that by the use of Solvay process "pure soda" a great saving in pots can be made. When salt cake is used the pots must be made much thicker, and even then they will not last so long. The presence of sulphate has a tendency to form scale on the pots, and when the scale forms they soon burn out. As there is absolutely no sulphate in the Solvay process "pure soda," this trouble is avoided and expense is saved. The great purity of the Solvay process "pure soda" is also an especial advantage to the makers of colored glass. Less coloring matter is required than is necessary with other makes.

Native carbonates of the United States.—Though so little soda ash is produced in this country, there are vast amounts of both the carbonate and sulphate occurring native in large lakes as well as in deposits in the western States and Territories. The "alkali belt," as it has been termed, lies west of the 100th meridian. A very interesting statement regarding this belt will be found in the census report on Chemical Products. Mr. William L. Rowland, the special agent in charge, estimates the consumption of soda salts in the United States in the census year at 398,500,000 pounds, of which but about 10 per cent., or 40,259,938 pounds, were produced here.

Common salt.—As both the sulphate and carbonate of soda are produced from the chloride of sodium (common salt), many attempts have been made to effect the direct union of silica and salt in the melting pot without the intervening and expensive processes, but so far with but little success. At present salt is used only for the commonest qualities of cheap colored glass, and to retard the action of the pure soda ash produced by the Solvay process.

Nitrate of soda.—Some little nitrate of soda (Chili saltpeter) is used as an oxidizing agent and as a decolorizer. Deposits of this salt occur native and in enormous quantities at Tarapaca, in Peru, where it forms a regular bed. Some beds are also reported as existing in Nevada.

POTASH.

As has been stated, the use of potash in the manufacture of glass is of comparatively recent date. The small amounts, rarely exceeding 2 per cent., sometimes found in ancient glass were derived from the vegetable sodas used, with which some potash is always associated. Some of the most expensive and beautiful glass of the present day, however, is made with potash. The Venetian glass houses of the Middle Ages, the products of which are held in such high repute, used potash made from the lees of wine and the ashes of fern. White Bohemian glass and the marvelously brilliant lead-flint of the English glass houses of to-day are potash glasses. The use of potash in glass very materially increases its cost. As a result soda is used in its stead wherever it can be done. The soda-lime-flint for all ordinary uses has almost entirely superseded the potash-lead-flint glass, and even in the manufacture of lead-flint the better and purer grades of carbonate of soda are taking the place, to some extent, of the more costly carbonate of potash.

Carbonate of potash.—The form in which this alkali is mixed in the batch is as carbonate of potash. While the best carbonate of potash is obtained from the lees of wine, this is too expensive for the glass maker. In large quantities it has for many years been made from wood ashes, and more lately from the residue of the manufacture of beet sugar and wine, and from the mineral carnallite of the Stassfurt mines. Potatoes, chestnuts, heather, sorrel, beet leaves, and tobacco stalks yield large proportions of potassium salts, but only a very small percentage of the total make of the world is derived from these sources. The forests of British America, Russia, Hungary, etc., furnish large quantities of wood ashes for the manufacture of potash, and the industry is still an important one in these districts. Large amounts of the carbonate are made from beet-root molasses, and the beet cake left after expressing the beet juice. Grape cake is a source of supply, as is also what is called "suint" or the wool of sheep impregnated with sweat; 100,000 kilos are produced from "suint" annually. Some is also made from the sulphate by the Le Blanc process. The potash resulting from the lixiviation of wood ashes is an impure carbonate which must be calcined and refined to fit it for the glass maker's use, the quality of the glass depending upon the degree of purification. This refined potash is known as pearl ash.

The chief sources of supply of potash are the French, German, and English chemical works, though the largest part of that used in this country is produced here. According to the report of Mr. William L. Rowland to the census office on Chemical Products and Salt, there were in the United States in the census year 68 establishments producing potash and pearl ash, producing 4,571,671 pounds, valued at $232,643. There was imported in the fiscal year ending June 30, 1880, crude potash to the amount of 564,807 pounds, and bicarbonate and pearl ash 405,941 pounds.

Of the remaining salts of potassium only the bitartrate and the nitrate are used in glass making, and to but a small extent.

LIME.

The use of lime as a glass-making material is of comparatively recent date. In the article on glass in Lardner's Cabinet Cyclopedia, published in 1832, it is stated that "lime in the form of chalk is useful as a cheap flux," but that it "can only be used sparingly," as it destroys the pots and clouds the glass. Six per cent. of lime is the maximum that can be used according to this author.

Though the use of lime is a recent discovery, it is nevertheless true that lime is found in all glass, both ancient and modern, except the lead-flint. This is a silicate of lead and potash or soda. With rare exceptions, all the other glass of commerce is a silicate of soda or potash and lime. The lime found in glass, until within a few years, has entered it with the soda or potash as a chance material, an impurity. It is to its presence, however, that we owe the preservation of many of the beautiful specimens of ancient glass that have come down to us. All glass is more or less soluble, soda glass especially so. Lime materially decreases this solubility, and it is the chance occurrence of lime in the ancient soda glass that has preserved it in the dampness of the tombs and ground where so much of it lay hidden for centuries.

Like most other materials, lime not only plays an important part in the reactions and processes that go on in the pot during the melting, but it imparts valuable properties to the glass. Glass rich in lime requires a higher temperature to melt, and because of this is more destructive to the pots, but used in proper proportions it promotes the fusion, and aids in the decomposition of the materials and improves the quality of the glass. Lime glass cannot compete with lead glass in brilliancy; but it is harder, not so easily scratched, holds its polish longer, is more elastic and consequently tougher, will stand higher temperatures, resists the action of water and chemical agents, and is very much more cheaply produced. Lime glass is also, because of the little difference in the specific gravity of the two silicates of which it is composed, less liable to become striated. In the manufacture of plate glass, which is ground and polished, it is found that glass which is rich in lime is harder to polish than that which is poor in lime, but it holds its polish better and longer. In a word, glass which is rich in lime is to be preferred by the consumer, but not by the producer. It has been asserted that lime glass is more liable than other glass to devitrify or to lose its vitreous, glassy structure, and become crystalline. It is probable that devitrification is the result of using an excess of lime and is not due to the use of lime itself, as the same phenomena are observed when an excess of sand or lead is used.

Lime is used in the batch both as caustic lime and as the carbonate. These are so well known and of such common occurrence as to need but little description. The carbonate of lime is one of the most abundant and widely diffused of materials, occurring in many forms, as the non-crystalline chalk, limestone, oölite and calcareous marl, the minute, granular, crystalline marble, and the crystalline Iceland spar. Lime is prepared from any of these carbonates, usually from limestone, by heating to redness, a red heat driving off the carbonic acid.

Either caustic lime or the carbonate, limestone, may be used in the batch in connection with carbonate of soda; but with sulphate of soda, as a rule, only the carbonate, usually as powdered chalk or limestone, is employed, though with sulphate the caustic lime is used. Concerning the use and effect of these, Mr. Henry Chance says: "It is a curious fact that while as regards the quality of the glass, chalk and limestone are found to answer equally well, glass made from the latter is harder and more difficult to grind than that which is made from the former. This may perhaps be due to the carbonate of magnesia which is generally present in limestone, but in a much smaller degree in chalk. Limestone possesses, moreover, the property of causing the glass to cool and set more rapidly when worked into shape." Lime, like all other glass materials, should be as free from impurities as possible, especially from oxide of iron.

The localities in this country from which good lime can be obtained are so many as almost to preclude any statement of them. A large part of both the lime and limestone used by the window-glass manufacturers of Pittsburgh is from Blair county, Pennsylvania. The limestone analyzes as follows:

Analysis of Blair county, Pennsylvania, limestone.

	Per cent.
Organic matter	.09
Silicic acid	1.01
Alumina	.02
Carbonate of iron	.165
Carbonate of magnesia	1.48
Carbonate of lime	97.23
	99.995
Metallic iron	.08

The lime-flint glass manufacturers of Pittsburgh use a different lime, chiefly from near Sandusky and Woodville, Ohio. The Sandusky lime analyzes as follows:

Analysis of Sandusky, Ohio, limestone.

	Per cent.
Hydroscopic moisture	.40
Silica	1.00
Organic matter	.05
Peroxide of iron	.12
Alumina	.40
Carbonate of magnesia	41.43
Carbonate of lime	56.60
	100.00

The annual consumption of limestone in the glass works of the United States is about 3,500 tons, and of lime 900,000 to 1,000,000 bushels.

CARBON.

The use of sulphate of soda in glass making necessitates the introduction of carbon into the pot to assist in its decomposition. The carbon is supplied by some form of coal rich in carbon, as anthracite, charcoal, or coke. As anthracite usually contains some iron, where purity of color is essential charcoal is the best. In converting the sulphate of soda into the carbonate in the Le Blanc soda-ash process, the salt cake is calcined in a furnace with chalk and coal dust. When sulphate is used in glass making a similar decomposition must be effected. This is brought about in the glass maker's pots in the presence of the same substances. Lime is always used in the batch, and charcoal is added as stated. Glass can be made with sulphate of soda without carbon, but with difficulty.

MANGANESE.

The black oxide of manganese (pyrolusite)(*a*) has long been used as a "decolorizer" in the manufacture of glass. Most ancient glasses contain it in small amounts, and it is probable that the "magnetic stone," which Pliny says was added in the manufacture of glass, was manganese. A common name for manganese, "glass-makers' soap," derived from the French "*savon des verriers*," is given it from its use to remove the color of glass.

Just how it acts as a decolorizer is a matter of some doubt. It was long believed that its only effect was to change by oxidation the protoxide of iron, which gives glass a decidedly green tinge, to the faint yellow sesquioxide; but Liebig suggests that the effect is not simply chemical but optical, the amethyst color communicated by the manganese counteracting the yellow or greenish yellow tint of the sesquioxide of iron, into which the protoxide is converted. Mr. Thomas Gaffield suggests that possibly both effects are produced, the manganese giving up a portion of its oxygen and its coloring power to the iron, which is converted into peroxide, giving a yellowish color to the glass, which color is complementary to whatever of purple coloring power is left in the manganese.

As the ores of manganese are usually so intimately associated with iron, great care must be exercised in procuring manganese as free from this element as possible, or the substance to be removed will be increased. Great care is also necessary as to the heat of the furnace when using manganese. If the heat is too low the oxide is not reduced and the glass has a pinkish tinge, or "high color," as it is termed; while if the furnace is too hot it is completely reduced and a greenish or "low color" is the result. Manganese is also useful for coloring glass purple or brown.

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[a] See also pages 550–566.

Some deposits of pyrolusite suitable for glass making are found in this country, but most of the deposits worked for manganese contain impurities that unfit it for glass. The manganese from the Crimora mine, Virginia, one of the chief sources of supply of this ore for the manufacture of ferromanganese, is too high in iron and cobalt for glass. At Powell's Ford, however, in the same State, a deposit is found that meets the requirements of glass making. This ore contains from 90 to 95 per cent. of binoxide of manganese, 0.02 per cent. of iron, and no copper or cobalt.

A manganese much used in the glass houses of the United States is a very pure pyrolusite from Nova Scotia. Analyses of this ore from the Crystal mine show from 90.50 to 98.05 per cent. of binoxide of manganese and practically no iron. The ore is crystalline, soft, and easily reduced to powder. Saxony and Turkey are also sources of supply of this material.

LEAD.

The use of lead as a glass-making material, except in the production of artificial gems, is an English invention of the seventeenth century, and grew out of the use of mineral fuel in the glass houses of that country in the place of wood. This fuel required pots to protect the glass from impurities from the coal, which so reduced the amount of heat that reached the materials as to demand a better flux; and lead, which is a powerful flux, promoting the fusion of the materials at a low temperature, was substituted. The result was not only to permit the use of the cheaper fuel, but the production of that most beautiful and brilliant of all glasses, the English flint.

Glass made with lead is more dense, has a greater power of refraction, and is less liable to breakage from sudden changes of temperature than either soda, potash, or lime glasses. It is soft and easily worked and scratched, but is of surpassing brilliancy, being only excelled by the diamond. The glass used for the manufacture of artificial gems is a lead glass, and it is to the employment of this material that they owe their brilliancy. It is very probable that the use of lead in a small way in the manufacture of these gems, which antedated its use in flint glass, suggested to the English glass maker its use in the covered pots. Lead is also used in the manufacture of optical glasses. The history of its use for this purpose is exceedingly interesting, but cannot be repeated here.

While two forms of lead, both oxides, are used in the manufacture of glass—litharge, the protoxide (PbO), and minium or red lead (Pb_3O_4)—red lead is preferred to litharge both on account of its more minute subdivision and because the oxygen evolved by its decomposition at the high temperature of the pots combines with any organic matter that may be present, carrying it off, and also peroxidizes any iron that may be associated with the materials.

Red lead is prepared from refined lead by simple oxidation in a furnace of proper shape. Two forms are used. The oldest is the ordinary egg-shaped cupellation furnace with cold blast, the flame producing the oxidation, entering at one end and playing over the molten lead in the line of the longer axis of the furnace, passing out at the other end. The red lead is produced in flakes, which are blown out of the furnace in a strong blast blowing in the direction of its shorter axis and across the flame, suitable channels being left in the furnace walls for the exit of the flakes on the side opposite to that from which the blast enters. This flake lead, as it is termed, which is a protoxide, is afterward heated in ovens to about 550° Fahr. and thus converted into minium.

In this process the red lead best adapted to glass making is not that from the flakes first or last produced from a given charge. The foreign metals easily oxidizable, as antimony, pass off with that first oxidized; while those more difficult of oxidation, as copper and silver and bismuth, remain until the last. All of these oxides except the lead are coloring matter, and greatly impair the limpid clearness which is so desirable in the glass in whose manufacture lead is used. The red lead from the flakes produced in the intermediate part of the process is preferable for glass making. This cupellation process, with the subsequent heating, is the one chiefly used in England in the preparation of red lead.

In this country red lead is produced usually by one continuous process. A reverberatory furnace, with the oxidizing flame playing in from two sides is used, the oxide remaining in the dish of the furnace until the entire charge is oxidized. All of the metals, therefore, remain in the red lead, and are diffused through the whole mass. Lead for the manufacture of commercial red lead, however, is first carefully refined, the silver, copper, antimony, bismuth, arsenic, and other foreign metals being removed, so that the total of impurities left in the oxide is exceedingly small. The red lead produced by this process is much better than that by cupellation.

Considerable red lead of the very best quality is produced in the United States from the "scraps" made in the process of corroding white lead. These scraps are the hard lumps of the imperfectly corroded white lead, and are simply put into a reverberatory furnace and oxidized. As the lead used for corroding must be quite pure, the red lead made from these scraps is also very pure. The lead furnished corroders will analyze 99.99 per cent. lead, and is guaranteed by certain refiners to contain less than 0.1 ounce of silver to a ton of lead. Indeed, silver in excess of this will destroy the whiteness of the paint, giving it a gray tinge. Practically no copper is left in corroders' lead, while highly arsenical pig leads or base bullion are not used at all in the manufacture of lead for corroders. The base bullions most used in making this grade of pig lead are those from Leadville (Colorado), New Mexico, Idaho, and portions of Montana and Utah.

The red lead made by corroders of this country is usually quite pure and excellent for glass making—equal, if not superior, to that of foreign make; but little of the latter being imported. The white lead manufacturers of Pittsburgh are supplying many of the glass works of that city with red lead that meets all of their requirements. Some of the glass works produce their own lead. One of the chief causes of poor red lead is imperfect oxidation. Some metallic lead remains with the red lead. This can be discovered by examination with a microscope.

It is stated that in England there is a great difference in the value of lead from the ores of different mines for the manufacture of red lead for glass making, certain ores having an enviable reputation for this purpose. To what this is due is not fully ascertained. Percy thinks it may be to the presence or absence of copper. The English lead ores, as well as the Spanish—which are those now chiefly used in England—are more of the character of the lead ores of Missouri and Illinois, and unlike those from the Rocky Mountain district. With marked exceptions, based upon certain impurities existing in too great abundance in the ores of certain mines, all the ores of the Rocky Mountain region named above are used for corroding and red lead manufacture. The guarantee of its purity is not the mine from which the ore is raised, for this is lost in the mass of base bullion, but the refiner's brand.

POT CLAY.

The pots or crucibles in which glass is melted are made from fireclay, which from this use is termed in the glass houses "pot clay."(*a*) In no part of the operations about a glass works is greater care and skill demanded than in the selection and preparation of the clay, the construction of the pots, and the setting of them in the furnace.

Fireclay for pot making should be practically infusible, unctuous to the touch, break with a clear, smooth, bright fracture, be free from lime and sulphide of iron, and contain as little oxide of iron as possible. The shale or slate clay of Stourbridge, England, is a typical pot clay, and is largely used. The clays of Andenne and Namur in Belgium, Forges-les-Eaux in France, Sargenau in Switzerland, Schwarzenfell in Bavaria, Klingenthal, the Palatinate and Bonn in Germany, and Glenborg in Scotland, are among the best known of European pot clays. In this country there are large deposits of excellent pot clays in many localities. Those that are used, however, are chiefly drawn from western Pennsylvania, Missouri, and New Jersey, though the clays of Maryland, Ohio, and Indiana are used to some extent. When American clay was first used it did not seem to give the satisfaction that its analysis would indicate. This was owing to a lack of skill in its preparation, but as this has been acquired, American clay is rapidly gaining in favor.

About one-half of the clay used in this country is foreign clay, principally German. Window, bottle, and plate-glass houses use the largest

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a See, also, page 684.

proportion of German clay, some making their pots entirely of German, others of a mixture of German and American. Nearly all the flint houses use pots made entirely of American clay, although a few mix some foreign. It is found by experience that the American (Missouri) clay will stand a more intense heat than any other, but that the German clay resists the action of the flux better; hence the mixture of the two to overcome as nearly as possible the two difficulties. American clay is fast superseding German clay because of the hotter running furnaces that are now being used. The American clay is much purer than the German, is more refractory, but not as dense. It is much less expensive.

The composition of pot clay from different localities is given in the following table:

Localities and kinds of clay.	Chemist or authority.	Silica, including sand.	Alumina.	Oxide of iron.	Lime.	Magnesia.	Carbonate of magnesia.	Potash.	Soda.	Sulphur.	Water.	Total.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Stourbridge, England:												
Homer's Best	Willis	67.34	21.03	2.03							8.24	98.64
Best Pot	Richardson	64.05	23.15	1.85			.10				10 00	99.15
Chance's	Percy	65.10	22.22	1.92	.14	.18		.18			9.86	99.42
Do	C. Tookey	63.30	23.30	1.80	.73						10.30	99.43
Scotch Glenborg	Professor Cook	61.45	24.68	1.67		.10		.20			10.90	
Belgium:												
Andenne	Bischof	46.64	34.78	1.80	.68	.41		.41			1.27	85.99
German:												
German	D. Tal Aran	46.44	36.95	1.64		.69			.48			
Do		70.60	23.60		.36	.45			1.10		3.89	
Coblentz	Professor Cook	71.31	15.66	1.19		.28		.63	Trace.		9.70	
Ebernhahm	Kerl	46.97	37.95	.95	.04	.11		3.00			10.02	
Grunstadt	Bischof	47.33	35.05	2.30	.16	1.11		3.18			10.51	
French:												
La Bouchade	Percy	55.40	26.40	4.20							12.00	
American:												
Cheltenham, Missouri:												
Crude	Litton	61.02	25.64	1.70	.70	.08		.48	.05	.45	9.68	99.80
Washed	do	59.60	26.41	1.61	1.00	.07		.29	.16	.38	10.48	102.00
Dixon, Missouri:												
Crude	Chauvenet and Blair	56.02	28.86	1.67	1.76	.34					11.12	
Washed	do	55.06	30.02	1.57	2.20	.41					10.54	
Blue Ridge, Missouri	Weiss	63.75	26.60	.75	Trace.	.85		.40		2.25	7.40	102.00
Oak Hill, Missouri	Chauvenet and Blair	64.32	22.82	1.75	.45	.12		.23	.54	.12	10.26	100.61
Christy's, Missouri		63.10	23.70	2.20	.09	.06		.04	.08		10.73	
Thomas, Pennsylvania	McKeown	43.88	40.96	.82	Trace.	Trace.					13.99	99.65
Blair county, Pennsylvania		70.18	20.99		.65	.13			.08		7.75	
Dixon's, New Jersey	Professor Cook	59.93	26.95	1.24		.07		Trace.	Trace.		10.20	
Near Newcastle, Delaware	Salvétat	72.33	16.75	1.29	2.00	.07					7.98	

The manufacture of the melting pots for a glass furnace is one of the most important, careful, and tedious of the operations about a glass works. From the digging of the clay till it is refined, mixed, kneaded, and put into pots, and these are thoroughly dried, heated, and set in the furnace, two or three years often pass. The pots themselves are costly, the setting difficult and expensive, and if they are improperly made, or spoiled in drying, heating, or setting, and break, the entire batch frequently is lost, and in many instances consequential damages ensue from the delays and loss of output. The importance of having good pots is so great that many manufacturers are not willing to depend upon outside makers to supply them, though this opposition to outside pot makers is not so great as it was a few years since. It is estimated now that about one-half of the pots used in the country are not made at the glass works. The clay, having been allowed to ripen or putrefy a sufficient time, is mixed into a thick paste with water and from one-fifth to one-fourth of its weight of finely ground old pots or "potsherds," and is thoroughly kneaded by tramping with bare feet until it is of the toughness of putty. This mixture dries more rapidly, contracts less when drying, and better resists the action of the fire and materials of the glass than the pure clay.

English and American pots are made without the use of molds or machinery. On the continent of Europe, however, machinery for their construction has been utilized and is largely in use, as is also a method of manufacturing pots in molds. These molds are of thick wood, strongly hooped with iron, and of the shape of the sides of the pots. A round mass of fireclay some 10 or 12 inches thick forms the bottom of the pot. Around this the mold, lined with strong cloth to prevent the adhesion of the clay, is placed. The lower portion of the sides of the pot is formed by beating down the middle of the mass of clay which forms the bottom, thus forcing up the outer portions against the side of the mold, the original thickness of 12 inches at the bottom being reduced to about 4 inches. Upon the portion of the sides thus formed the remaining part of the sides of the pot is completed by building up with rolls of clay worked by the hand against the sides of the mold.

As indicated, English and American pots are made without the use of molds, the left hand of the workman taking the place of the mold, supporting on the outside the walls of the pot while he builds it up on the inside little by little with his right hand. Care must be taken to keep the pot entirely free from air cavities. The pots are not built up at once, but after placing a layer each pot is permitted to stand and set, being kept carefully covered. A good pot maker and his assistants can furnish one pot a day. After the pots are made, great care is taken to dry them thoroughly. In summer the natural temperature is sufficient, but in winter they are kept at from 60° to 70° F., care being taken not to allow them to freeze. The pots are allowed to dry from four to eight months, and when they are ready for use their temperature is very gradually and cautiously increased, first in a warmer room and then in the annealing arch, until they reach the temperature of the working furnace, when they are immediately placed in the furnace or "set." The soundness of the pots is tested by throwing a small lump of coal against the side. If it rings well it is regarded as a good pot, but if dull it will probably be short lived, though this test is not always conclusive.

The setting of the pots is one of the most difficult and laborious operations at a glass works. Mr. Henry Chance remarks: "The terrible task of setting these pots in the furnace falls upon the glass-house crew, and the nicety with which these enormous vessels are adjusted in their place, in the teeth of a consuming fire, is perhaps that operation which, in the many marvels of glass making, would most astonish a stranger to such scenes."

The average duration of open pots is about seven weeks, but some attain the age of ten or twelve weeks, while others, as every manufacturer well knows, terminate their existence prematurely, either from the naturally defective constitution of the pot or from bad treatment in the pot arch, or, more frequently, from its having been "starved," that is, exposed to a current of cold air in the furnace through the neglect of the attendant. Flint pots have a much longer life, averaging perhaps three months, single pots sometimes lasting ten months. In a 10-pot lime-flint furnace, at Pittsburgh, but 21 pots were set in a year.

The breakage of a pot often disturbs the furnace to such an extent that the breakage of others frequently follows, and many weeks will sometimes elapse before the disorganization thus produced can be rectified. The loss of a pot and the metal contained is nothing as compared with the injury which the glass in the surviving pots, and the pots themselves, are apt to sustain.

MINERAL WATERS.

By A. C. Peale.

That the production of mineral waters in the United States is a subject of increasing importance, especially when viewed in its commercial aspect, is evident not only from the fact that every year adds to the number of improved mineral springs in all portions of the country, but also that the imports of natural mineral waters increased from 394,423 gallons in the fiscal year 1873 to 1,714,085 gallons in the fiscal year 1883, and in 1884 dropped to 1,534,664 gallons, while, according to the reports received by this office, the domestic production of mineral waters put upon the market increased in the calendar year 1884 to 68,720,936 gallons from 47,289,743 gallons in 1883. The returns for 1884, however, are fuller and more reliable than those for 1883.

From an economic point of view mineral springs are interesting in at least three different ways: First, as places of resort they add to the wealth and population of their localities; secondly, the waters when bottled are shipped to distant portions of the country and not infrequently are sent abroad; and, thirdly, the bottled waters, or in some cases the salts left upon evaporation of the water, become a portion of the stock in trade of druggists and dealers in mineral waters.

It has long been well known that the United States abounds in mineral springs, among which all classes of water may be found. That the majority are unimproved is due mainly to the comparative newness of our country and the consequent sparseness of population, especially in the Territories and extreme western States, and also to the fact that our springs have not as yet been made the subjects of careful and complete investigation as in the case of so many foreign springs. Many of the springs allowed to run to waste would in most European countries be of considerable value. Still there has been an improvement in this respect; and even now a mineral spring in this country is frequently a source of profit to the owner.

Detailed lists of the mineral springs and analyses of their waters have been compiled in connection with the present work, but are omitted for want of space. They will appear in a separate publication.

Although the object of this paper is to present a statistical view, still it is necessary to define the term "mineral water," especially with reference to its scope as used here. The definition will depend somewhat upon the point of view. Water is itself a mineral, and in a strict sense all waters holding gaseous or mineral substances in solution are mineral waters, no matter how small the quantity may be. Usually, however, the term is restricted to those waters which contain an unusual amount of mineral matter or which are characterized by an unusual degree of heat. In a therapeutical sense all waters that have an effect upon the animal body are mineral waters. Interesting as they are from a scientific standpoint, and important as they undoubtedly must be in the elucidation of certain geological problems, it is mainly from their use as medicinal agents that they derive their commercial importance. Therefore in the following summary all springs have been included which come under the head of "mineral springs," using the words in the widest sense of the definition, where the springs have been improved as resorts or where the waters have been placed upon the market, and restricting the mention of unimproved springs so far as possible to those mineralized to a more or less marked degree. The table being thus made fairly complete, the proportion of the mineral springs utilized is easily seen. Many springs have been included which upon a hasty glance might seem to be unworthy of a place. It must be remembered in this connection that had the enumeration been made ten years ago a large proportion of the springs now used as places of resort would have been reported as unimproved, and there is no doubt that future lists will include many of the now unimproved springs under the head "improved." Many of the noted resorts of Europe were once obscure villages, and owe their importance, and in some cases world-wide celebrity, to the discovery and improvement of mineral springs. The building of a railroad near a mineral spring, furnishing easy access to it and a mode of transportation for the waters, or the increase of population in the surrounding district, are often factors in the development of mineral springs, and will doubtless increase the importance of many of the unimproved springs.

MINERAL-SPRING LOCALITIES.

Alabama.—Although but few of the mineral springs of Alabama are used commercially, many are important as places of resort, and several are well known throughout the country at large.

Alaska.—The hot and mineral springs of Alaska, according to Dr. William H. Dall, are both numerous and important. There are many springs which do not freeze even during the most severe weather, and which are therefore properly thermal springs. As far as learned, none of the waters of the Alaskan springs have ever been analyzed.

Arizona.—The table is probably not complete, as alkaline, sulphureted, and saline springs are so numerous in some portions of the Territory as not to be taken notice of. Only the principal springs are included. As far as can be ascertained, every one is unimproved. Thermal springs abound, and will doubtless be utilized as the country becomes more thickly populated.

Arkansas.—Among mineral-spring States Arkansas occupies a prominent place. The reputation of her famous Hot Springs, which have been known from the earliest years of this century, having attracted attention to the subject, has probably led the people of the State to appreciate the value of their springs, and therefore, in proportion to the population and the number of springs in the State, a larger number have been improved than in any other State, with the possible exception of California.

California.—The Pacific coast is remarkable for the number of its mineral springs, and California stands at the head of the list, having probably more than any other State, east or west. A large number of the California springs are utilized, and are annually visited by thousands of persons. Many of the springs are thermal; for volcanic rocks, with which thermal springs are naturally associated, are found in many portions of the State. A large number of the springs are in comparatively inaccessible regions and of course are little known, much less used as resorts. One spring in Inyo county is considered so valuable that the water is transported first on pack animals 40 miles and then by rail 60 miles to San Francisco, where it is sold at a high rate. The Geysers, in Sonoma county, are probably the best known springs in the State.

Colorado is rich in mineral springs, both hot and cold, and a fair proportion, considering the newness of the State, have been improved. Manitou is the best known resort.

Connecticut.—The mineral springs of Connecticut are comparatively unimportant. They are mainly weak chalybeates, the majority of which are unimproved. The proximity of Saratoga Springs seems to have affected them so far as extensive use is concerned. Prof. C. U. Shepard, in writing of them in 1837, speaks of the springs at Stafford as being the most important in the State, which is still the case. A number of others, however, seem to have considerable local reputation.

Dakota.—Information as to mineral springs in Dakota is meager, and the data are insufficient for the making of a complete list. In some of the southeastern counties are springs and wells in which the water is said to be chalybeate, but correspondence does not develop much in relation to them beyond the fact that they are unimproved. In various portions of the Territory alkali is quite abundant in the soil, and the water passing through it naturally becomes impregnated. Localities of this kind are found along the Little Missouri and in the Black Hills. In Newton and Jenney's report on the geology of the Black Hills the following statement is made: "Springs issuing from the black clay-shales of the Cretaceous on Beaver creek were found to be strongly acid and astringent to the taste, turning blue litmus red, and probably containing alum and free sulphuric acid. Similar springs were reported to be found near Buffalo Gate, on the southwestern side of the Black

Hills." The Chicago and Northwestern Railway Company has had several wells and springs analyzed, and these are shown to be mineralized.

Delaware.—Chalybeate springs are numerous in various portions of the State, but they are of little importance.

District of Columbia.—Many of the wells and springs within the limits of the District are slightly chalybeate, but none, even the strongest, is of sufficient importance to warrant its inclusion in the table. At Uniontown or Anacostia, opposite Washington, is a well the water of which is said to be quite strongly impregnated with iron. Springs of similar character exist in the vicinity of Le Droit park, northeast of the city; and a well now filled in or unused on Louisiana avenue between Ninth and Tenth streets, in Washington, is said to have been strongly chalybeate.

Florida.—The springs of Florida are noted for their size rather than the great quantity of mineral matter they contain. Some of the streams proceeding from them are large enough to float steamboats. When mineralized, sulphureted hydrogen gas seems to be the principal ingredient. Most of the springs in the southern and eastern parts of the State would be classified as weak sulphur springs. In the northeastern portion of the State, in the vicinity of Jacksonville, the springs are more frequently chalybeate. The temperatures of the Florida springs are remarkably uniform summer and winter, and the springs that are utilized are mainly winter resorts. None of the waters are sold.

Georgia.—In the few general works on the mineral springs of the United States very little space is given to Georgia. Only five or six localities are usually enumerated; whereas the State has about thirty which are more or less improved as places of resort.

Idaho.—Thermal springs are frequent in Idaho, as would naturally be expected when its geological structure is remembered. The country is principally mountainous, and where it is not so is covered to a great extent with lava flows. Granitic and volcanic rocks prevail, and, in connection with the mountain corrugation, present favorable conditions for the development of warm and hot springs. Many are used for bathing. None of the waters are used commercially.

Illinois appears to have a fair proportion of mineral springs, among which chalybeate and sulphureted waters are most numerous.

Indiana is prominent among the northern central States in the number of its known mineral springs. As in the case of its neighbor, Illinois, chalybeate and sulphureted waters are most abundant.

Indian Territory.—The list of springs for this Territory is doubtless incomplete so far as the actual number of springs is concerned, as very considerable portions in the western and northwestern sections are comparatively unknown. Several of the springs are places of resort. These are used mainly during the summer by persons who camp near them so as to use the waters for medicinal purposes. The localities as far as reported are unimproved.

Iowa.—Mineral springs are not common in Iowa, although many wells, both artesian and ordinary, are frequently charged with mineral matter. The occurrence of acid springs is notable and interesting.

Kansas.—The mineral waters of Kansas are derived mainly from artesian wells and are principally saline and sulpho-saline, and have been developed to a certain extent. Many of them have considerable local reputation for medicinal effects.

Kentucky occupies a prominent place as a mineral-spring State, not only from the number of its springs, but also on account of the quality of the waters. Some of them are among the most remarkable in the country, and are found on sale in the East and West, North and South. The majority, however, are still unimproved and neglected, although a large number are used as local resorts during the summer season.

Louisiana.—Data as to Louisiana springs are somewhat meager. None of the waters are used commercially, and those springs utilized as resorts appear to be mainly of local importance.

Maine.—A considerable portion of the mineral springs of Maine are utilized both commercially and as resorts. They are all cold, none being warm enough to be considered thermal, even in the widest use of the term. They belong to the classes of chalybeate, sulphureted, alkaline, and saline springs.

Maryland.—The general works on mineral springs give no space to Maryland, and Dr. Pepper's list includes but one locality, the Carroll White Sulphur Springs of Alleghany county. The State has, however, a considerable number of quite important springs, and many that are unimportant.

Massachusetts.—The mineral springs of Massachusetts are few in number and of little note. They are mainly chalybeate. A few are used commercially, and some were at one time well kept and widely known as resorts. At present few are improved. The Hopkinton springs were noted at one time and largely resorted to, but at present are not utilized to any great extent.

Michigan.—The mineral waters of Michigan are derived principally from wells, although these are termed mineral springs. Many of these wells are artesian and were sunk originally for other purposes. A large number are popularly called "magnetic," from supposed magnetic properties of the water.

Minnesota.—At present only a few of the springs are developed.

Mississippi.—The mineral springs of Mississippi are numerous, and several of them have considerable reputation beyond the limits of the State. In certain localities the greater portion of the wells and springs are highly mineralized and appear to be used extensively, and sometimes indiscriminately, by the residents for medicinal purposes. The number of waters used commercially is small.

Missouri.—This State is rich in mineral springs; but comparatively few of them are improved. As far as known, the springs are similar to most of those in the adjacent States, as would be expected, the geological formations being similar.

Montana.—The proximity of the Yellowstone National Park to Montana, and the fact that the readiest access to the park has been from that Territory, accounts, possibly, for the fact that so little has hitherto been published in relation to its mineral springs in general works. The wonderful phenomena of the geyser regions have overshadowed the lesser springs. Montana, however, possesses many important springs, among them one which bears a close resemblance to the celebrated Apollinaris spring of Prussia. Several localities of thermal springs have been improved and used extensively as resorts. The majority of the springs are thermal and are found in the western and more mountainous portions of the Territory.

Nebraska.—Nebraska is one of the few States for which no mineral springs are reported. Springs of any kind are of comparatively infrequent occurrence, particularly in the western portion of the State, though, doubtless, the waters of certain portions, as in the neighboring States of Kansas and Iowa and in Dakota, will be found to be somewhat mineralized when artesian and other wells are sunk. Salt springs are found in the eastern part of the State, also near the head of the Elkhorn and Loup rivers. There is a saline artesian well at Lincoln, but so far as known none of the salt springs are used medicinally.

Nevada.—Nevada occupies a prominent place among mineral-spring States. Springs both hot and cold (the former predominating) are found in every county. The warm or hot springs are found mainly in connection with geological fault lines, or fractures in the strata. Many have been used by the Indians for medicinal purposes. A number are utilized in the same way by the whites, and in case of the hot and warm springs for bathing, with beneficial results in cases of rheumatic diseases.

New Hampshire.—Although the mineral springs of New Hampshire are utilized as resorts to a considerable extent, they are not as a rule highly mineralized. A fair proportion are used commercially and have considerable local reputation.

New Jersey is not conspicuous for the occurrence of mineral springs. Unimproved weak chalybeate springs could doubtless be found in many portions of the State, but they would be of little importance.

New Mexico.—It is probable the list is far from complete. Alkaline and saline waters, both hot and cold, are doubtless more prevalent in certain portions of the State than are pure waters. Many of the hot springs have a widespread reputation, and some were doubtless used years ago by the Franciscan and Dominican friars, and prior to that by the Indians.

New York.—New York is distinguished among her sister States by the number of her mineral springs. They are also of great variety and many are sources of profit to their owners. The Saratoga springs are the most widely known of American springs, and Saratoga has many namesakes in other States.

North Carolina enjoys the distinction of being one of the two States on the Atlantic coast possessing hot springs. Otherwise her mineral springs are not different from those usually found along the coast or in the region of the Appalachians. Chalybeate and sulphur springs are of common occurrence. A fair proportion are places of resort, and a few are used commercially.

Ohio.—Prof. Edward Orton, of Columbus, says, referring to the belt of black Devonian shale which traverses the State from Lake Erie to the Ohio valley: "This formation as a rule yields but little water; the springs issuing from it, except at the very base, are weak, but they carry iron and sulphur almost everywhere. In Adams county, for example, if there is one mineral spring there are thousands. Four are credited on the list. One of these is a place of resort, but the others are identical in character with hundreds of others on all sides. They have come into recognition possibly through the superior intelligence or energy of their proprietors, who call attention to them in one way or another. What is true of Adams county is equally true of Scioto, Pike, Ross, and Pickaway, and to a less extent of the northern counties that hold the shale. The list in Delaware county might be increased to hundreds. The springs issuing from the base of the formation often have good volume, and these make a group by themselves. The same remark applies to the so-called chalybeate springs derived from the Drift formation." "There are considerable districts in which a bed of bog ore underlies the Drift beds, and all wells and springs in these districts might be called chalybeates."

Oregon.—Oregon is well supplied with valuable hot and cold mineral springs. Many are improved and utilized for medicinal purposes, especially in the western portion of the State. Warm and hot springs are numerous.

Pennsylvania.—Very little has ever been published with especial reference to Pennsylvania mineral waters. Several of the springs have been popular resorts for years, as in the case of the Bedford springs. Others, as the Bath spring at Bristol, have declined in importance. The latter was a resort in revolutionary times. Some of the springs, like those at Ephrata, Yellow springs, and Caledonian springs, are places of summer resort, but the waters can scarcely be called mineral waters, as they are merely notable for their purity and their situation.

Rhode Island.—So far as known there is no record of mineral springs existing in Rhode Island. A reference to a spring said to be near Woonsocket was received, but nothing could be definitely learned in regard to it. There may possibly be a few unimportant springs in the State, and if so they are likely to be simply weak chalybeate waters.

South Carolina.—Chalybeate springs are said to abound in this State. Many of the springs have considerable reputation at home, and several, Glenn springs among them, are well known beyond the State limits. Some of the artesian wells in the Charleston district possess medicinal properties. Only one spring, so far as reported, has any commercial importance.

Tennessee.—The geological formations of Tennessee being the same as those in the adjacent part of Kentucky and in the northern part of Alabama, the mineral springs are naturally of the same general character as those found in these States. They occur in all portions of the State. Many springs are used to a large extent locally, and several as places of resort rank with any in the adjoining States. Very few are used commercially.

Texas.—There are at least fifteen localities in the State that are places of resort, and there are a great many springs the waters of which have at present only a local reputation. There are mineral springs in thirty counties. The Lampasas springs, the Sour Lake springs, and Hynson's iron springs appear to be among those most widely known.

Utah.—All the earlier explorers and travelers who crossed Utah noted the presence of mineral waters and of thermal springs, especially in the region of Great Salt Lake. They occur mainly in connection with faulted strata and are generally strongly saline and frequently sulphureted. Only a few are used as resorts even locally, and none are known to be at present of commercial importanee. The springs near Salt Lake City are best known and most used.

Vermont.—The springs of Vermont are not unlike those of the other New England States, and most of them have been known for a long time. Clarendon springs were used as long ago as 1776.

Virginia.—Virginia occupies the same position among the south Atlantic that New York does among the north Atlantic States in respect to the number and variety of its mineral springs. More than fifty localities are places of resort, and among them are some of the most famous in the country. Although the spring area proper is in the Appalachian region, mineral springs are also found east of the Blue Ridge on the more level country that stretches toward the coast.

Washington.—The number of mineral springs is small. The Medical lake is the best known spring and the only one that is now of commercial value. As the Territory becomes more settled the number of known springs will doubtless be increased.

West Virginia is noted for its mineral waters. They are thermal, saline, chalybeate, alkaline, carbonated, sulphureted, and acid. The best known springs are in the eastern and southeastern portions of the State, especially in the Alleghany mountains. There are, however, several well-known and important springs and mineral wells in the western counties. When the central portion of the State, which is rugged and mountainous, becomes more settled many springs will probably be discovered.

Wisconsin possesses valuable mineral waters, many of which have a reputation and are largely sold in all portions of the country.

Wyoming.—The table includes twenty-seven localities, exclusive of the Yellowstone National Park, in which there are a dozen sub-localities and more than two thousand springs and geysers. As the Territory becomes better known the list of springs will probably be largely increased, especially in the northern portions of the Territory. The water from a spring at Soda Butte in the National Park is sometimes seen on sale in Montana.

Mineral springs of the United States.

States and Territories.	Number of spring localities.	Number of individual springs.	Number of springs analyzed.	Number of spring localities utilized as places of resort.	Number used commercially.	Number from which reports have been received.
North Atlantic States:						
Maine	35	43	18	9	8	8
New Hampshire	11	25	8	6	4	3
Vermont	30	43	10	9	6	2
Massachusetts	18	23	5	2	3	3
Connecticut	16	20	2	2	2	0
New York	213	309	70	23	34	20
New Jersey	13	13	7	1	0	0
Pennsylvania	44	75	28	15	4	2
South Atlantic States:						
Delaware	5	5	0	0	0	0
Maryland	24	78	4	3	1	1
Virginia	93	270	75	53	20	12
West Virginia	35	62	19	15	6	5
North Carolina	66	147	18	29	7	6
South Carolina	28	32	6	5	1	1
Georgia	52	256	20	29	2	2
Florida	25	37	4	10	0	0
Northern Central States:						
Ohio	76	95	14	16	6	6
Indiana	104	151	30	17	7	6
Illinois	49	58	10	6	3	3
Michigan	39	71	26	17	4	2
Wisconsin	73	131	55	15	15	11
Minnesota	22	35	5	2	1	1
Iowa	20	46	8	4	3	2
Missouri	124	398	23	21	6	4
Dakota	9	9	5	0	0	0
Kansas	7	32	6	3	2	2
Southern Central States:						
Kentucky	112	282	78	16	4	1
Tennessee	169	290	14	57	7	4
Alabama	83	218	18	23	5	5
Mississippi	76	99	5	10	1	1
Louisiana	15	28	0	6	0	0
Texas	01	456	10	20	7	5
Indian Territory	8	10	0	3	0	0
Arkansas	107	456	5	23	5	5
Western States and Territories:						
Alaska	25	25	0	1	0	0
Wyoming	39	2, 254	7	4	1	0
Montana	41	144	8	6	0	0
Colorado	68	354	37	14	1	1
New Mexico	35	90	11	5	1	1
Arizona	26	30	3	0	0	0
Utah	32	118	5	3	0	0
Nevada	104	153	6	10	0	0
Idaho	31	113	2	3	0	0
Washington	10	15	1	2	1	1
Oregon	34	55	8	11	2	1
California	207	354	41	38	9	2
Total	2, 544	8, 008	735	567	189	129

PRODUCTION.

Natural mineral waters sold in 1883 *and* 1884.

	Number of spring localities reported.	1883.		1884.	
		Gallons sold.	Value.	Gallons sold.	Value.
North Atlantic States	38	2, 470, 670	$282, 270	3, 345, 760	$328, 125
South Atlantic States	27	312, 090	64, 973	464, 718	103, 191
Northern Central States	37	41, 196, 129	343, 480	60, 576, 141	626, 862
Southern Central States	21	1, 441, 042	139, 973	1, 526, 817	147, 112
Western States and Territories	6	169, 812	52, 787	307, 500	85, 200
	129	45, 589, 743	883. 483	66, 220, 936	1, 290, 490
Estimated for localities not reporting	60	1, 700, 000	256, 000	2, 500, 000	375, 000
Total	189	47, 289, 743	1, 139, 483	68, 720, 936	1, 665, 490

IMPORTS.

Mineral waters imported and entered for consumption in the United States, 1867 *to* 1883 *inclusive.*

Fiscal years ending June 30—	In bottles of 1 quart or less.		In bottles in excess of 1 quart.		Not in bottles.		All, not artificial.		Total.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	
	Bottles.		*Quarts.*		*Gallons.*		*Gallons.*		
1867	370, 610	$24, 913	3, 792	$360		$137			$25, 410
1868	241, 702	18, 438	22, 819	2, 052	554	104			20, 594
1869	344, 691	25, 635	9, 739	802	1, 042	245			26, 682
1870	433, 212	30, 680	18, 025	1, 743	2, 063	508			32, 931
1871	470, 947	34, 604	2, 320	174	1, 336	141			34, 919
1872	892, 913	67, 951			639	116			68, 067
1873	35, 508	2, 326			355	75	394, 423	$98, 151	100, 552
1874	7, 238	691			95	16	199, 035	79, 789	80, 496
1875	4, 174	471			5	2	395, 956	101, 640	102, 113
1876	25, 758	1, 899					447, 646	134, 889	136, 788
1877	12, 965	1, 328				22	520, 751	167, 458	168, 808
1878	8, 229	815					883, 674	350, 912	351, 727
1879	28, 440	2, 352			3	4	798, 107	282, 153	284, 509
1880	207, 554	19, 731					927, 759	285, 798	305, 529
1881	150, 326	11, 850			55	26	1, 225, 462	383, 616	395, 492
1882	152, 277	17, 010					1, 542, 905	410, 105	427, 115
1883	88, 497	7, 054					1, 714, 085	441, 439	448, 493

In 1884 the imports were as follows:

	Gallons.	Value.
Artificial mineral waters	29, 366	$4, 591
Natural mineral waters	1, 505, 298	362, 651
Total	1, 534, 664	367, 242

EXPORTS.

Exports of natural mineral waters, of domestic production, from the United States.

Fiscal years ending June 30—	Value.	Fiscal years ending June 30—	Value.
1875	$162	1881	$1, 029
1876	80	1882	421
1879	1, 529	1883	459
1880	1, 486		

The exports of artificial mineral waters are insignificant.

HISTORICAL SKETCH OF MINING LAW.

By Rossiter W. Raymond.

The question of the nature of private ownership in mines, and of the relation of the State to both public and private lands containing valuable mineral deposits, may be discussed either upon general grounds of public policy and political theory or by the historical method of studying its development in society and through custom and law. In other words, we may inquire what the rights and the duties of the state ought to be, according to certain assumed principles, or we may inquire what they have come to be and are likely to become, through the actual experience of nations, and of our own nation in particular. And, having settled this point, we may take up the further inquiry, What part of these governmental powers and duties belongs to the national authority, and what must be left to the several States?

A priori, it may be said that the Government acquires jurisdiction of a peculiar character over the mining industry by reason of the unique character of the industry itself, as constantly tending towards a permanent exhaustion of the natural resources of the land. The deterioration of soils through ignorant or reckless agriculture may be cured in time by wiser methods; forests wantonly destroyed may be replanted; fishing grounds left to themselves or restocked artificially may recover their prolific abundance of supply, but coal, iron, copper, lead, petroleum, gold, and silver will not come again within the history of the human race into the places from which they have been extracted. A waste of them is a waste forever.

It is true that neither the world in general nor any country so large and so richly endowed by nature as ours is in immediate danger of the actual exhaustion of its mineral resources. The time when all the coal will have been burned up or all the iron will have been mined is still too remote to have any special bearing upon political economy. But history is full of examples of local and (so to say) commercial, though not actual, exhaustion of such resources. Abandoned mining districts, even on the virgin soil of the United States, are a familiar feature, while in older countries these landmarks of former industries and civilizations are numerous enough. To take a striking instance at home, we may reflect upon the extraordinary development of the petroleum production of the United States and the surprising spectacle which it presents to-day of an immense overproduction and a correspondingly depressed market, coupled with the approaching certainty of a complete exhaustion of the territory known to be oil-bearing. It is notorious that this industry, left to itself without governmental interference, has been conducted with such recklessness that even the records of experience gained in it have been lost for the most part, and the sources of supply have been in many cases needlessly impaired, while the supply itself has been wasted. Considering the national importance of this article, both for domestic comfort and for foreign trade, we are tempted to believe that a governmental regulation of the petroleum business would have been justifiable and beneficial.

But reflection may convince us that it is, on the whole, wise to leave industry untrammeled, even at the risk of occasional loss of public wealth, which a strict supervision might have saved. At all events, a democratic Government is not well adapted to assume the paternal attitude. In the long run, it is not likely to know more about the needs of the country, or of any individual industry in it, than the citizens engaged in that industry. As Herbert Spencer has pointed out, it is conspicuously unfitted to do those things which, in his opinion, Government ought not to try to do; and its well-intentioned endeavors to control the acts of the citizens are likely to be blunders in policy, while they are almost certain to become encroachments upon liberty. We leave, therefore, even the waste of timber, anthracite, and petroleum to the operation of self-interest, and exert the authority of the state only so far as may be necessary to preserve the public peace and safety, and to secure the mutual respect, among individuals, of individual rights, putting the mining industry, in this respect, on the same basis as any other. We have, perhaps, gone too far in this direction. Better so than to have gone too far in the other. The following passage from the address of Hon. Abram S. Hewitt, president of the American Institute of Mining Engineers, in 1876, on "A Century of Mining and Metallurgy in the United States" (Transactions of the American Institute of Mining Engineers, Vol. V., page 183), states the matter in a nutshell:

"Turning to the State and Territorial legislatures, we find that they have, in some cases, provided for inspecting mines in the interest of the safety of workmen. Perhaps the best law of this kind is that of Pennsylvania, in which State the peculiar perils of coal mining have forced the legislature to take measures of protection. But we find nowhere such a technical control of mining as is exhibited in many European states, where the Government requires of the miner that he shall not waste wantonly or ignorantly the resources which, once exhausted, will never grow again. Our people waste as much as they like and no one interferes. Admitting that this is an evil, it still remains a matter of doubt how far, under the circumstances of our particular case, the supervision of authority could remedy it. For my own part, though inclined to restrict as far as possible the functions of Government, I am not disposed to say that for so great an end as the conservation of the mineral wealth of the country it may not properly enforce some measures of economy with as good right as it may forbid the reckless waste of timber or the slaughter of game out of season. But in our nation, at least, governmental interference is the last resort, and a poor substitute for other causes, which, in the atmosphere of freedom and intelligence, ought to be effective. We are, perhaps, in our material career as a nation, like the young man who has 'sown his wild oats,' and now, by mature reflection and the lessons of experience, is likely to be better restrained than by the hand of parental authority."

The other method of inquiry above referred to, namely, the historical, is worthy of greater attention than it has received with relation to this subject among American authors. The present writer has given in the article "Mining," in Lalor's "Cyclopedia of Political Science," an outline of the history of mining jurisprudence, which may be consulted by those who are interested. For readers of German, the files of the *Zeitschrift für Bergrecht*, a quarterly magazine edited and published at Bonn, Germany, by Berghauptmann Brassert, afford a treasury of information and acute criticism. Acknowledgment is here made particularly to a paper on the taxation of mines by Dr. Ad. Arndt, of Halle-an-der-Saale, published in that magazine, Vol. XXIII. (1882), page 18, from which many facts have been taken. Another authority of which abundant use has been made is the dissertation of Dr. J. F. Reitemeier (Göttingen, 1785), entitled "Geschichte des Bergbaues und Hüttenwesens bei den alten Völkern."

The purpose of this paper is to present such an outline of the history of mining law, and its present form in other nations, as may facilitate an intelligent study of the questions presented by the relations of the mining industry to the Federal, State, and Territorial governments of this country.

ANCIENT MINING TENURES.

Prehistoric mining.—So far as can be inferred from the traces which remain (such as the extensive gold and copper workings of a nomadic pre-Tartar race in Siberia, the ancient copper mines of Lake Superior, the mica mines of North Carolina, the turquois mine of New Mexico, etc.), the earliest mining was apparently carried on by individuals and without permanent ownership of land. But the nature of the industry, even more than that of agriculture, tends to fixity of tenure; and this is the secret, in fact, of the intimate relation between mining and civilization. Civilization involves order and law—that is, the protection of property and the enforcement of contracts—and thus permits the investment, as distinguished from the hoarding, of wealth. Mining and the manufactures dependent upon it both require and create civilization, because, to a greater extent than nomadic pursuits, or even agriculture, they require fixed capital, operate for future profit, and are unable to run away when threatened.

Phœnician and Egyptian mining.—It is, therefore, not surprising that under those early civilizations in which despots controlled both wealth and labor, mines should appear as royal property. Originally acquired, with all other forms of property, by conquest, they were retained by the conquerors. Sometimes enterprising adventurers, like the Phœnicians, traded throughout foreign countries, buying not only the metals but also mining rights. In other cases sovereigns operated their own mines by the labor of purchased slaves, convicts, and prisoners of war. The descriptions of the horrors of the Egyptian mines, furnished by classic writers, are often quoted.

Greek mining.—The petty sovereigns of the Grecian islands were mainly the owners of their mines. There is a record of one instance in which a mine royalty was paid amounting to one-tenth the gross product, namely, by the gold and silver mines of Siphnos to the Delphic Apollo. The drowning of the mines by the rising of the sea, at a later day, was attributed to the anger of the deity at the discontinuance of this religious tribute.

The republic of Athens owned extensive mines, which were leased in "claims" of size fixed by law. The lessee or "locator" paid to the state a certain fee for his privilege, and also one twenty-fourth of the gross product. At the beginning of the Persian war the annual income from this source was about $30,000, which was distributed among the citizens. There were also extensive mining operations in the provinces of the Macedonian Philip, which fell, with the rest, into the hands of the Romans.

Roman mining.—The Romans found the art of mining actively practiced by many of the European tribes which they overcame. The iron of Elba, the gold of Lombardy, the gold, silver, copper, and iron of Gaul, and the gold, silver, lead, iron, and tin of Britain, were known to them. Above all, the mines of Spain, Sicily, and Sardinia, which had made Carthage strong to wage war upon Rome, were the rich booty of the first two Punic wars. After these, successive conquests secured the mines of Asia Minor, Greece, Macedonia, Asia, Egypt, Gaul, and Britain. There were thus two classes of mines under Roman law, those owned in Italy by private citizens (which seem to have been held and taxed like other property), and those in the provinces, which belonged by right of conquest to the state.

The system of farming the revenues pursued by the Romans extended to the provincial mines. According to a recently discovered fragment of mining regulations, the *procurator metallorum* leased the mines to private persons or companies, and farmed out the collection of the royalties or rents to a *conductor*. The system proved ruinous as well as cruel. The lessees employed vast numbers of slaves, and robbed the mines without regard to anything else than the maximum profit to be secured during the term of their leases. The result was an immense temporary productiveness, followed by a corresponding exhaustion and reaction. The emperors effected many reforms. They caused a stricter inspection of the operations of mining to be maintained;

they discontinued in large part the employment of slaves (except convicts), and in many cases a sort of feudal relation grew up with the inhabitants of the mining districts, who worked under the Government supervision, and paid a certain tribute in money or in kind, retaining for themselves the remainder of the product of their labor. There seems to have been no uniform rule as to the amount of tribute. It was fixed in various ways, according to the circumstances of each case; but the guiding principle appears to have been that the miner's share should amount merely to wages for his work, and the state or the landowner should have the rest. In special cases, explorations were encouraged by grants of privilege.

MEDIÆVAL MINING LAWS.

Barbarian mining.—The mining industry of the Western Empire was first overwhelmed by the barbarians. The Byzantines held out longer, but at last they too succumbed, and the mines of Asia Minor, Thrace, and Greece fell to the Arabs. There are hints in history of rude and limited mining operations by the Arabs in Spain, the Franks in Gaul, and the Goths in Italy; but the period down to the eleventh century is practically a blank.

The German mining freedom.—The codes of the Middle Ages show that all mines were considered the property of the sovereign, independently of the ownership of the land. The right of the sovereign (reckoned among the *regalia*) was, however, in practice a right to grant permits for mining and to receive certain tributes from it, and its exercise was modified by the rise of an entirely new principle—that of the German *Bergbaufreiheit* or "mining freedom"—which was the earliest form of what we call, in the western mining districts of the United States, "the right of the discoverer." This appears first as a local custom, remarkably prevalent in the German mining districts, according to which every citizen had the right to mine wherever he discovered metalliferous deposits not covered by a previous claim. It has been suggested that this immemorial custom sprang from the *Markgenossenschaft*, an early form of communism, in which the land of a *Mark* was held in common, and redistributed annually. Such a redistribution not being fairly practicable for mining lands, it might come to pass that they would be left in the hands of the same occupants, so long as they continued to work with suitable industry, and would revert to the commune when abandoned.

As the titles to land became vested in individuals, the right of the mining discoverer would come into conflict with that of the land owner. It would conflict also with the claim of the sovereign. But since the sovereign principally cared for the revenue, and the miner was willing to pay a fair tribute, a compromise in the latter case was not difficult. By "granting" the *Bergbaufreiheit*, and insisting only upon the tribute, the sovereign saved his dignity and the most valuable part of his *regalia.* As for the land owner, he was recognized by neither party. Both the custom of miners and that of kings recognized the existence of a property in minerals separate from the surface ownership. The doctrine, so familiar to us, that the owner of the land owns all beneath it to the center of the earth, and all above it *usque ad cœlum*, was not only unknown, but its exact opposite was declared by the authorities of that age. Thus the *Sachsenspiegel* quaintly says: "All treasure lying hidden in the earth deeper than a plow goes, belongs to the power of the king," and the king gave it to the miner.

The German miners, carrying their *Bergfreiheit* with them, penetrated into the Roman and Sclavonic provinces; and the first written code which remains to us, expressing the relation above described, is from one of these mining colonies—the famous agreement made March 24, 1185, between the Bishop of Trent, in the Italian Tyrol, and his German miners, characterized in the quaint Latin of the document as *Argentarii, qui solent appelari Silbrarii.*(a)

According to this treaty, concluded between Bishop Albrecht and a representative committee of the miners, mining is declared free to all, rich and poor, on the semi-annual payment to the bishop of certain specified fees, in lieu of all taxation. The bishop guarantees protection and also immunity from ordinary legal process, except in cases of personal injury committed by a miner. In other words, questions of mining rights, etc., arising among the miners, are to be decided by themselves, and according to their own rules and customs. They on their part agree to increase their annual tribute if new discoveries shall augment their profits, and also, that, if the bishop shall fall into financial difficulties, they will lend him money.

It happens that this bishopric of Trent and its flourishing community of miners furnished occasion for the commencement of a struggle that lasted for more than a century between the emperors and the territorial lords. The mining freedom established by Bishop Albrecht was undisturbed during his time, but his successor, Conrad, was summoned before an imperial tribunal by the emperor, Frederick I., who laid claim to the Tridentine silver mines on the ground that, according to usage elsewhere (in Lombardy), they should be included among the *regalia.* The dispute was settled in a way characteristic of the times. The bishop kept the mines (or, more strictly, the right to receive the annual dues), but consented to accept them as the gift of the emperor, who thereupon, in 1189, solemnly granted to his late antagonist the rights in controversy, "that his generous kindness to the church and its representative might be reckoned a service to God." What the emperor gained by this settlement was a precedent strengthening his claims elsewhere. It is noteworthy, however, that the privileges of the miners themselves

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a The text, published in von Sperge's *Tyrolische Bergwerksgeschichte* (Vienna, 1765), is quoted in full by Tuscani, in the *Zeitschrift für Bergrecht*, Vol. XVIII. (1877), page 337.

do not seem to have been called in question. Probably if the emperor had won his cause, the old treaty would have been ratified by him.

The general principle of "mining freedom," and a body of unwritten maxims regulating the tribunals of miners, doubtless originated as early as the ninth or tenth century. The earliest written codes, which bear date in the thirteenth century, give internal evidence that they are but records and arrangements of pre-existing rules. The famous Iglau code, established about 1250 by King Wenzel I. of Bohemia, was the source and model for many others, and was itself probably derived from the ancient *Bergrecht* of Freiberg, which again doubtless grew out of the customs brought thither in the twelfth century by miners from the Harz.

German codes.—A brief summary of the Iglau code[a] will suffice to indicate the general nature of mediæval German mining law. This curious document is in Latin, and bears the seals of Wenzel, king of Bohemia, and his son, the margrave of Moravia. After a pious and wordy prelude, it ordains that certain officials shall fix the boundaries of mining claims, and defines the dimensions of these and the conditions on which the possessory title of the miner may be acquired and maintained. The full size of the surface granted, when unoccupied space permits, to a single mine is 479 feet along the course of the vein by 196 feet in width. A certain proportion of the claim is set apart for the king, another for the town, or the original owner of the land. Special rights of administration and judgment are accorded to the mining courts of Iglau, and various principles and methods are laid down for the decision of intricate cases of conflicting claims. The thrifty burghers of this mining city (*Bergstadt*) won fame and profit by keeping the provisions of this code a secret, and acting under their guidance as arbitrators in questions of mining jurisprudence referred to them by other provinces. One of the most frequent causes of dispute was the privilege conferred upon the party driving a deep adit, which, by draining the water from the mines of other parties, and by facilitating their ventilation, was held to entitle the owner to a share in their profits. To secure this reward and other incidental "adit privileges," the adit must be a certain distance below any other similar work and must be prosecuted under certain conditions.

Apparently gold and silver mines only were at first the subjects of such legislation. The right to other minerals appears to have gone with the ownership of the land, or at least to have been claimed by the land owner.

The quadripartite conflict in the empire.—There were thus, in the thirteenth century, four parties more or less in conflict over mining rights—the emperor, the territorial princes, the miners, and the land owners.

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[a] Repeated here from the author's article on "Mining" in Lalor's "Cyclopedia of Political Science." The code itself is given in Count Caspar Sternberg's "Geschichte der böhmischen Bergwerke."

This confusion was simplified by the "golden bull" of Charles IV. (1356), which surrendered to the electors the claims of the emperor, and excluded also the land owner, putting all metals, precious or base, together with salines, under one rule, that of the territorial sovereigns. (*a*) The latter, wisely encouraging the industry of mining, vied with each other in grants of privilege to mining cities, which thus became centers of science and jurisprudence as well as of wealth. The famous seven mining cities of the Harz, and the "ancient and honorable free mining city of Freiberg," in the realm of the Saxon counts of Meissen, are examples.

The number of electoral princes in the empire was very great; and by their grants and assignments the number of "mining lords" (*Bergherrn*), that is, of those who controlled mining rights, was made still greater. Since nearly all of them issued special mining codes, these were correspondingly numerous, and increased the complexity of German mining law. In one point the codes agree, namely, in the assertion of the exclusive mining right of the *Bergherr*. But this right was variously exercised. Sometimes certain minerals were reserved to be mined by the *Bergherr;* sometimes the reservation applied to specified territory; sometimes absolute grants of the mining right for given areas and for specified minerals were made, with or without provision for tribute; sometimes mining was made free, subject to such special grants; that is, exploration for minerals and on territory not thus excepted was thrown open to all, with the promise that discoverers of valuable minerals should receive definite grants of mining ground at a certain rate of tribute, usually one-tenth, sometimes only one-twentieth, of the product.

Apart from the reservations above named, the general type of a German code of the fourteenth, fifteenth, and sixteenth centuries was somewhat as follows: It included free, or nearly free, exploration (buildings not being imperiled, and damages to surface or to agriculture being chargeable to the explorer); the immediate announcement (*Muthung*) of a discovery made; the issue of a preliminary permit; the survey, location, and regular grant of the mining ground, after the deposit had been sufficiently exposed; the obligation to prosecute the work continuously, unless natural causes, such as foul air or excess of water, prevented; the payment of royalty to the *Bergherr;* the division of a mining enterprise into shares (*Kuxe*, usually 128 in number); the furnishing of mine timbers by the crown forester, or by private owners under agreements and regulations supervised by the crown officers, etc. The driving of adits was the privilege of the *Bergherr*, but it was very generally conceded to private parties, with the appertaining advantages and revenues. It was common to give the lord "by ancient usage," one-eighth of the stock in every leased mine. He was, however, liable to assessment

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[a] The words are: *Universas auri et argenti fodinas atque mineras stanni, cupri, ferri, plumbi, et alterius cujusque metalli, ac etiam salis tam inventas quam inveniendas.*

like any other stockholder, and forfeited his stock by non-payment. Mining leases covered a certain area of the surface and a space below the surface, either bounded by vertical planes or by surfaces parallel with the dip of the vein. The first was called a square location (*Geviertfeld*), and the second an inclined location (*Gestrecktfeld*). The possessor of an inclined location was generally allowed to work about 21 feet (3½ *Lachter* or fathoms) into the hanging wall (roof) of his vein, and an equal distance into the foot wall (floor), and to extract all ore found within these limits, as well as in the vein proper, which he might follow indefinitely downward (*in die ewige Teufe*). The simple square location was applied to beds, masses, and even to true veins, when they dipped not more than 15° below the horizontal.

French mining law.—In France the king was able to maintain his claims against the feudal lords. The patent of Charles VI., issued May 30, 1413, declares that to him and not to *ceux qui ont jurisdictions hautes, moyennes et basses*, belong all mines everywhere in his kingdom, and the right to collect the mining tithe, and ordains, in the exercise of this sovereignty, that every miner may mine freely anywhere, even under the surface owned by another, provided the said tithe be duly paid—*payant à nous notre dixième franchement.*

English mining law.—The principle of mining freedom took little root, apparently, in England. Perhaps the sole trace of it in recent times is the custom of "tin bounding" in Cornwall and Devon. The number of Cornish mining terms which betray a German origin indicate that the enterprising German miners of the Middle Ages probably found their way to that region and left their mark upon both institutions and language. But in this case the British crown has left its mark also, though only in the way of a ratification of the miners' custom. King John declared in his patent of October 29, 1201, that all tin mines in the whole of his kingdom belonged to him(*a*), and graciously authorized all miners to dig for tin wherever they chose. The claim by prerogative to all gold and silver mines as property of the crown is an immemorial one in England, and it was not until the reign of William and Mary that tin, copper, lead, or iron mines could be owned and freely worked by the subject if their ores contained intermixtures of the precious metals. In the celebrated "case of mines," in the reign of Elizabeth, the ground of the royal claim was thus stated from the bench: "The common law, which is founded upon reason, appropriates everything to the persons whom it best suits, as common and trivial things to the common people; things of more worth to persons of a higher and superior class; and things most excellent to persons who excel all others; and because gold and silver are the most excellent things which the soil contains, the law has appointed them, as in reason it ought, to the person most excellent, and that is the king."

Strictly speaking, the crown has never surrendered its right to mines of

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a Stannariæ sunt nostra dominica.

pure gold or silver or either of these mixed with other metals than tin, copper, lead, or iron. But practically in Great Britain, the mineral right of whatever kind originates in the ownership of the soil, although it may be alienated and separately conveyed by the act of the owner, who must, however, to make such conveyance effective as a basis for mining, expressly grant, not only the minerals, but also the right to enter upon his lands, dig, and carry away the minerals. Usually also the right to occupy the surface with roads, buildings, machinery, waterways, etc., is specified.

The custom of tin bounding is recognized as "ancient" by the charter granted to the stannaries of Cornwall in the third year of King John. It was thus defined in a modern case at law (Rogers *vs.* Brenton, 10 Q. B., 26): "That any person may enter on the waste land of another in Cornwall, and mark out by four corner boundaries a certain area; a written description of the land so marked with metes and bounds, and the name of the person for whose use the proceeding is taken, is recorded in an immemorial local court, called the stannary court, and proclaimed at three successive courts held at stated intervals; if no objection is successfully made by any other person, the court awards a writ to the bailiff of the court to deliver possession of the said 'bounds or tin-work' to the bounder, who thereupon has the exclusive right to search for, dig, and take to his own use all tin and tin ore within the described limits, paying to the land owner a certain customary proportion of the ore raised, under the name of 'toll tin.' The right descends to executors, and may be preserved for an indefinite time, either by actually working and paying toll, or by annually renewing the four boundary marks on a certain day." The custom in Devonshire, it is said, is a freehold interest descending to the heir and unaccompanied by the obligation to pay any toll to the land owner. It would probably be held void in law, since even the Cornish custom was pronounced by Lord Denman, in the case above cited, to be sustainable only by actually working and paying toll.

MODERN CODES.

Returning now to the development of mining law on the continent of Europe, we find that in the eighteenth century both the claims of the land owner and the complaints of the miner began to make themselves heard. In different states, different minerals were exempted from the tribute imposed on mining, and released to the owners of the land. Coal throughout Germany, and iron ore in some provinces (*e. g.*, Silesia), were among these exemptions. The mining of other substances was embarrassed by many regulations and burdens. Thus in Prussia the officials of the crown fixed the price of the product, determined the dividends or assessments of the private stockholders, appointed mining captains, engaged laborers, etc., and the mines paid extra for this paternal supervision, so that although the nominal tribute was but one-tenth, the total contribution amounted not infrequently to more than 20 per cent. of the gross product. These exactions and interferences, coupled with the practice on the part of the state of reserving for its own operations the most profitable minerals and the best territory, caused a dissatisfaction on the part of the mining communities which ultimately brought about important changes.

France.—The first effect of modern ideas in this respect was seen in France. The Constituent Assembly (1791) decreed, under the influence of Mirabeau, that the mines and mineral deposits of France were the property of the nation, and authorized the Government to grant temporary "concessions" of them, giving preference to the land owner, to whom was also expressly reserved all that part of every mineral deposit lying within a hundred feet of the surface. But the law of 1810 (*Code Napoléon*) finally fixed in its present form the French system. It declares that the property in minerals goes with the property in land, but that the Government may separate the two, granting the mineral right to another, even in perpetuity, on the condition of a tribute paid to the land owner. *Mines* only are subject to these conditions; *minières* (open workings or diggings) and *carrières* (quarries) are left to the land owner. Salt works are reckoned as *mines.* The payments of miners to the state comprise a fixed annual fee of 10 francs for each square kilometer (about 247 acres) of mining ground, a tax (formerly variable, but fixed in 1839 at 5 per cent. of the net profit), and certain contributions (*centimes additionnels*) for administrative purposes. A law passed July 27, 1880, provides that without the consent of the land-owner no prospecting license or mining concession shall be sufficient to authorize digging or the erection of buildings, etc., in walled inclosures, courts, or gardens; or the location of shafts or adits within 50 meters of buildings or their adjacent walled inclosures. Under these restrictions, and after certain formalities (including advertisement), an applicant for license or concession may obtain authority to take possession of the necessary surface for his work. If his occupation lasts but one year, and the land can then be used as before, the land owner receives as damages twice the net annual income of the land. If the occupation is longer than a year, or if it permanently injures the land, the owner can force the miner to purchase the property at twice the value which it had before mining or exploration began. No mining operations are allowed to be conducted in such a way as to endanger the safety of the mine, the workmen, or the public, the maintenance of highways, the stability of dwellings, or the permanence of mineral springs, or springs constituting the water supply of towns, farms, or public institutions.

Belgium, etc.—The principles of the French system have been imitated in other countries. Where the *Code Napoléon* has survived, this system has usually been retained. It remained in force until 1865 in the Rhine province of Prussia. It is still in force in Belgium, where, however, the tax on profits is but 2 per cent., instead of 5; and in Luxembourg, where the oölitic iron-ore mines lying deeper than 35 meters are the subject of "concessions," and the Government had, down to 1883, granted away 992 hectares (2.47 acres each) out of a total of 2,002 hectares of such mineral lands, in 50-year leases, at 750 francs per annum per hectare granted, or else 37,500 francs per hectare actually worked out.

Greece.—The Greek law of 1861 is imitated from the French, and contains the same distinction as to mines, open workings, and quarries. Mines are granted by the Government. The land owner receives a proportion not exceeding 5 per cent. of the net profit. The state receives annually 30 centimes per hectare of the concession, and a proportion of the net profit, not exceeding 5 per cent.

Italy.—The Sardinian law of 1859 is similar. It distinguishes between mines and open workings. The former are worked under royal concession. The fixed tax is 50 centesimi per hectare of surface (but not to amount in any case to less than 20 lire or francs), and the proportional tax is 5 per cent. of the net profit.

Mexico.—The Spanish ordinance of mines, published in 1783, has been substantially in force until the present year in Mexico, and was the law in the territories which the United States acquired from Mexico by conquest and purchase. It asserts the right of sovereignty over all species of metals, and authorizes concessions, dependent upon continuous working and annual tribute. It is also very full in its directions as to the manner of mining, attempting to correct in this way the tendency to reckless robbery of mines, inevitable under such tenure. The size of claims (invariably "square locations") is regulated by the dip of the vein, as shown by a shaft 30 feet deep; the length of the claim along the course of the vein being 200 yards (*varas*) and the width varied from 100 to a maximum of 200 yards, according to the dip, the smallest width being granted to a claim on a vertical vein, and the greatest on a vein departing 45° or more from the vertical. These measures are so calculated that under the most frequent circumstances (the dip varying from 45° to 60° from the horizontal) the vein will pass out of the claim at the vertical depth of 600 feet, at which depth, the ordinance naively remarks, it is commonly much exhausted. It need hardly be said that the introduction of steam engines and the construction of deep adits have long since rendered it possible to mine to the depth of 4,000 feet. The taxation of Mexican mines has always been heavy—especially when the export tax on bullion is included. Spain did for her American provinces what Carthage and Rome had done for Spain; and the spirit of her legislation, the desire to wring as much plunder from the rich mines as possible, lingered in the land after the Spanish rule had been overthrown.

Recent events, however, promise a more liberal policy, calculated to attract and protect foreign capital. By an amendment to the constitution, the control over mining and mining judicature, previously vested in the several States, has been given to the central Government, which has issued a new code, based upon the Spanish ordinance, but containing important amendments, which bring it into greater harmony with modern conditions and methods. Having received, up to the time of completing this article, merely general accounts at second hand, of this new code, I prefer to make, at the present time, no further comment upon it than this simple mention of its appearance.(*a*)

Spain.—The modern Spanish law of 1859 declares all inorganic, metallic, combustible, saline, and calcareo-phosphatic substances, occurring in such a way as to be obtained by mining, to be the property of the state, and subjects of its concession, without which no one can dispose of them. The so-called *Basas para la nueva legislacion de minas* of December 29, 1868, established three classes, corresponding to the French *carrières*, *minières*, and *mines*. Minerals of the first class (chiefly the earthy minerals and rocks) are left to the land owner. The second class comprises placers and alluvial deposits of metals, bog-iron ores, and old ore and slag heaps. This class also is left, first, to the land owner, but may, under certain conditions, be granted by the state to another. The third class comprises ore deposits in general, and mineral combustibles, with asphaltum, petroleum, graphite, salts, and vitriols, sulphur, precious stones, etc. The concessions granted in the second and third classes are subject to the following annual tax: On mines of precious stones and metals (except iron ore) 20 pesetas (francs) per hectare. On all others, 8 pesetas per hectare. This is the rate fixed by the law of December 31, 1881. Previously the tax was half as great, viz., 10 and 4 pesetas for the two grades respectively; but there was an additional tax of 1 per cent. of the gross product, which is now

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[a] Since this article was prepared, a digest and discussion of the new Mexican law has been presented to the American Institute of Mining Engineers, in a paper by Mr. R. E. Chism, an American mining engineer residing at Saltillo, Coahuila, entitled "The New Mining Code of Mexico," read at the Chattanooga meeting, May, 1885, and to be permanently published in Vol. XIV. of the Transactions of the Institute. By this code coal, rock, clay, placers of iron or tin, salt, and springs of all kinds—fresh, salt, thermal, medicinal, petroleum, or gas—are the exclusive property of the land owner. Other mineral deposits constitute a realty distinct from the soil, to be acquired by denouncement and concession, and held under conditions of working prescribed by the law. Exploration, both on private and on public lands, is permitted—in the latter case with special conditions, such as bonds of indemnity to surface owners, etc. Denunciation must follow within one month of the expiration of the exploring permit, which is granted usually for one month, and may be extended to two. The "claim" is a "square location," being, on lodes, 200 meters long, and from 100 meters (for a dip of 85° or more) to 300 meters (for a dip of 45½° or less) in width. On placers of precious metals or stones, the claim is 20 meters square; on flat-lying veins or irregular deposits, 300 meters square, or, if such deposits are of iron ore, 500 meters square. Mining products are free of all taxes on their circulation within the republic; quicksilver is free of import duty or direct tax, and for fifty years all mines of coal, iron, and quicksilver are exempt from direct taxation of any kind. Other mines will pay (apart from coinage or export duties) not more than one direct tax, which will not exceed 2 per cent. of the gross value of their product. Metallurgical establishments pay taxes like other manufactories.

abolished. The number of mining concessions in Spain at the end of 1877 was 14,928; the average size, 19 hectares; or, more accurately, 5,782 concessions of the 4-peseta class averaged about 30 hectares each, and 9,146 of the 10-peseta class averaged 12 hectores. The total area granted was 283,728 hectares (about 700,000 acres).

Germany.—Great advances have been made in recent years, in the simplification of the mining codes of Germany. The initiative and the model, in this respect, was furnished by the Prussian law of 1865. This law, with slight modifications, is now in force in twelve German states, representing 90 per cent. of the area and of the mineral products of the empire, viz., Prussia, Bavaria, Wurtemberg, Alsace-Lorraine, Hesse, Anhalt, and Brunswick. It expresses two tendencies—the one towards a wider recognition of the rights of the land owner, the other towards a withdrawal of the Government from undue interference with mining (either by competition or by control) and a reduction of the burdens of special tribute and taxation. The inclined location is no longer granted, and the miner is confined to the space inclosed by vertical planes drawn through his surface boundaries. The maximum size of a location is in Prussia 500,000 square *Lachter* (2,189,000 square meters, equivalent to about 540 acres), except in certain districts where for local reasons the maximum size is only one-twentieth as great. The permission of the land owner is necessary to preliminary explorations, though he may be compelled by the authorities to give it, yet only upon receiving a bond of indemnity. A mining grant is not forfeited by ceasing to work it, unless the authorities, for sufficient reason, insist upon the resumption of work, in which case the grantee has a right of protest and appeal and six months' grace. The numerous fees, royalties, and tithes of former times are done away, and in their place a moderate tax is imposed—in Austria, Saxony, and Bavaria, a tax on net profits; in Prussia, a tax on the value of the product of 1 per cent. for the general treasury of the state and 1 per cent. to cover the expenses of supervision. Iron mines are generaly, if not universally, free of royalty to the state. Benefit societies for miners (*Knappschaftsvereine*) are established by law. Bog-iron ore, gold nuggets in the soil (in Prussia), gold placers (in Bavaria), coal (in Saxony and some other states), iron (in Silesia), salt and salines (in Hanover), mineral springs and amber (except in East Prussia and West Prussia, where amber found in the sea or on the beach belongs to the state) are exceptions to the mining law, and belong to the land owner.

Austria.—With regard to the Austrian mining law (comprising the codes in force in Bohemia, Hungary, Bosnia, etc., as well as Austria proper) it is sufficient to remark here, that like the mediæval German codes, it contains the two principles of *Bergregal* and *Bergfreiheit*, and that, like the modern German codes, it shows (though not in all provinces of the empire equally) the tendency to a practical surrender by the state of the *Bergregal*, and the substitution of a merely regulative power over mining. Salt mines are a state monopoly; many other mines are state property; coal and iron mines are generally the property of the land owner. The remainder of the mines of the empire are generally the objects of temporary or permanent grants. The revenue of the state from the mines thus granted is made up of license fees for prospecting, rents paid per unit of area granted, and taxes upon gross or net income.

Russia.—The mines of Russia are chiefly on the Asiatic side of the Urals. They have been administered as a source of revenue to the state or the czar in various ways. Grants have been made to various noble families, out of which princes like the Demidoffs have amassed great fortunes. The crown has carried on large operations upon private account; and finally a sort of mining freedom has been introduced to increase the revenue from the public lands. For an elaborate account of these measures and their results, the reader is referred to the chapters contributed by Mr. E. Delmar Morgan, F. R. G. S., the well-known explorer of Central Asia, to Mr. Lock's book on "Gold," already cited.

Great Britain.—Modern legislation in regard to mines in Great Britain is confined to the support of a Royal School of Mines, the collection of statistics, the maintenance of inspectors, and the enforcement of certain regulations for the safety of miners and the public, the protection of children, etc. The principal statutes are the Coal Mines Regulation Act, 1872 (35 and 36 Victoria, chap. 76), and the Metalliferous Mines Regulation Acts, 1872 and 1877 (35 and 36 Victoria, chap. 77, and 38 and 39 Victoria, chap. 39). There are other acts relating to explosives, education, the employment of children, and the liability of employers for injury to workmen, which bear incidentally upon mining.

British colonies.—The mining laws of Australia and Canada follow the principles of English law, modified by old grants of the crown and by the fact that in these colonies large areas of unoccupied public land exist, on which the local governments may authorize mining, on such terms as they may choose to make.

In New South Wales, the authority to dig or mine for gold is given to all who apply for it.(*a*) It costs 10*s*. per year, and entitles its possessor to take up ground upon any gold field to the extent of 60 feet by 60 feet, or from that to 114 feet by 114 feet, according to the nature of proposed operations. For quartz mining the claim unit is 50 feet along the reef (lode) by 100 yards on each side. Sluicing claims extend to 10 acres. The miner's right includes half an acre for a dwelling and the electoral franchise.

In New Zealand the annual license fee for "miner's right" is £1, to which is added £1 per acre for ground held on miner's lease, and some registration fees and a gold export duty of 2*s*. per ounce, which is indi-

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a See, for the statements here made concerning New South Wales, New Zealand, Tasmania, and Victoria, "Gold, its Occurrence and Extraction," by Alfred G. Lock, F. R. G. S., (London, 1882), pages 479, 523, 527, 628, 641, and 895.

rectly a tax on the miner. The usual maximum claim is 16½ acres. But the government has in special cases, to facilitate expensive operations, granted larger areas (*e. g.* 50 acres).

In Tasmania the mining regulations are exceedingly liberal. The miner's right costs 10*s.* per annum. Alluvial claims are for a single miner 25 yards square; for two partners, 50 by 30 yards. Larger areas are granted to discoverers. Lode claims are 200 yards along the lode by a width of 250 yards. For deep workings, 21-year leases can be obtained at 10*s.* per acre per annum. Dams and machinery sites may occupy 10 acres and a quarter of an acre is allowed for a dwelling.

In Victoria a similar system obtains. At the end of 1880 the area in this colony occupied as "mining claims" under the by-laws of the several district mining boards was 35,126 acres, while 24,430 acres were held under leases from the crown.

Canada.—The mining law of Canada (apart from the police regulation of mining) is found in the act of April 14, 1872, which declares that "no reservation of gold, silver, iron, copper, or other mines or minerals shall be inserted in any patent from the crown granting any portion of the Dominion lands;" that "any person or persons may explore for mines or minerals on any of the Dominion lands, surveyed or unsurveyed, and not then marked or staked out and claimed or occupied, and may, subject to the provisions hereinafter contained, purchase the same;" that the surveyed lands shall be sold in legal subdivisions, and land in unsurveyed territory and beyond the "fertile belt" shall be sold in blocks or "locations" of 80 by 40 chains (320 acres), or 40 by 40 chains (160 acres), or 40 by 20 chains (80 acres); and that the secretary of state may withdraw mineral land from sale, and lease it at a royalty not exceeding 2½ per cent. of the net profits of working it. The act also fixes the price of mining as well as farming lands at $1 per acre; but the secretary of state is authorized in his discretion to put up lands at auction and sell to the highest bidder.

The United States.—The limit of space originally allotted to this review having been exceeded, it is deemed advisable to stop at this point, without entering upon the history of mining rights and legislation in the North American colonies and subsequently in the United States. This department of the subject has been treated by a number of writers and compilers, among whom may be recommended, as giving comprehensive and suggestive views of the past and present condition of our mining law, Mr. Gregory Yale ("Mining Claims and Water Rights," San Francisco, 1867), Mr. Henry N. Copp ("United States Mining Decisions," Washington, 1874, "United States Mineral Lands," Washington, 1882, and *Land Owner*, Washington, monthly), and other compilers and editors of departmental and judicial decisions, and of various statutes. The police regulations of the different States as to mining have now been collected in one place. The laws of Pennsylvania and Ohio are probably the most elaborate, the conditions of coal mining in these States having demanded a degree of attention in the interest of public safety not yet required elsewhere. Of governmental control in the interest of economy, to prevent the waste of mineral resources, there is, as intimated in the beginning of this article, no trace in American legislation—not even in the flagrant case of the reckless robbery of the petroleum resources of Pennsylvania. As the writer has elsewhere shown (*a*), the idea of the *Bergregal* does not exist in American law. The right of the land owner is supreme; and even when the Federal Government has legislated concerning mining titles it has done so for public lands only and in its capacity as their owner, with the power, given to the land owner by the English common law, of separating the estate in minerals from the estate in soil and disposing of either upon any terms which it might dictate.

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a In the Reports of the Commissioner of Mining Statistics, in communications appended to the Report of the Public Lands Commission, and in various papers in the Transactions of the American Institute of Mining Engineers.

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