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Q, Quartzite G. Granite. B, S, Black Shale, D, Dolomite; B, L, Blue Limestone. P Porphyry, 1, Smuggler Mine; 2, J C. Johnson; 3, Enterprise; 4, Veteran; 5, Millanee
6, Franklin; 7, Aspen; 8, Spar; 9, Durant; 10, Pioneer

ASPEN LOOKING UP ROARING FORK.

GEOLOGY

OF

COLORADO AND WESTERN ORE DEPOSITS

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BY

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PREFACE.

This treatise contains the substance of a series of elementary lectures delivered by the author to the students of the Colorado State School of Mines. It is published with a view of meeting some of the needs of the general public, of the ordinary miner, and of the unscientific many, rather than with an idea of offering technical matter for the discussion of the scientific few. The materials are derived from the writer's own researches, and from the most reliable resources available to him, such as the standard text-books and the valuable published reports of the United States Geological Survey. The writer having for a time been connected with that survey, knows full well how high a value is to be attached to those reports, which must remain for all time as a standard of reference for those interested in the geological relations of the mines of Colorado and Western States.

The first part of the work contains a rough sketch of general Geology, for the benefit of those who are not familiar with the terms used in this science. The sketch is further applied to the local geology of Colorado. The second part refers to the phenomena of veins and ores, and their surroundings, as illustrated by Colorado.

The third part contains a brief account of some of the principal mining districts of Colorado, not as official reports of those districts, but as examples to illustrate the principles of the preceding parts.

The fourth part gives a sketch of some of the principal mines and mining regions of the West outside of Colorado, with much the same illustrative idea in view.

PART I.

GENERAL GEOLOGY.

To assist such of our readers as may not be very familiar with the science of Geology, in understanding such technical and geological terms as are unavoidable in this treatise, we offer a rough general outline of the earth's history, applying it afterwards to a sketch of the geology of this particular region of Colorado.

ORIGIN OF THE EARTH.

The world was not "spoken into existence ready made" in the state we now find it. It has attained this condition through a multitude of gradual changes and revolutions which have taken millions of years to accomplish. The remote history of the earth is a matter of hypothesis. There are reasons for supposing that at one time its elements were in a gaseous condition, and that this planet was an incandescent luminous cloud revolving through space, gradually consolidating into a molten ball, surrounded still by an atmosphere of gases, a condition perhaps not unlike the present one of the sun, whose interior is supposed to be passing into the molten state while its exterior consists of various incandescent gases arranged more or less according to their specific gravities. The spectroscope has detected the elements of some of our earth metals and minerals in the sun in a state of vapor.

Upon the cooling of the ball, a crust formed like that on molten iron, crumpled, by contraction due to cooling, into an uneven surface with slight elevations and depressions, and doubtless broken through, here and there, by great fissures and volcanic craters, through which the molten flood beneath poured out in volumes.

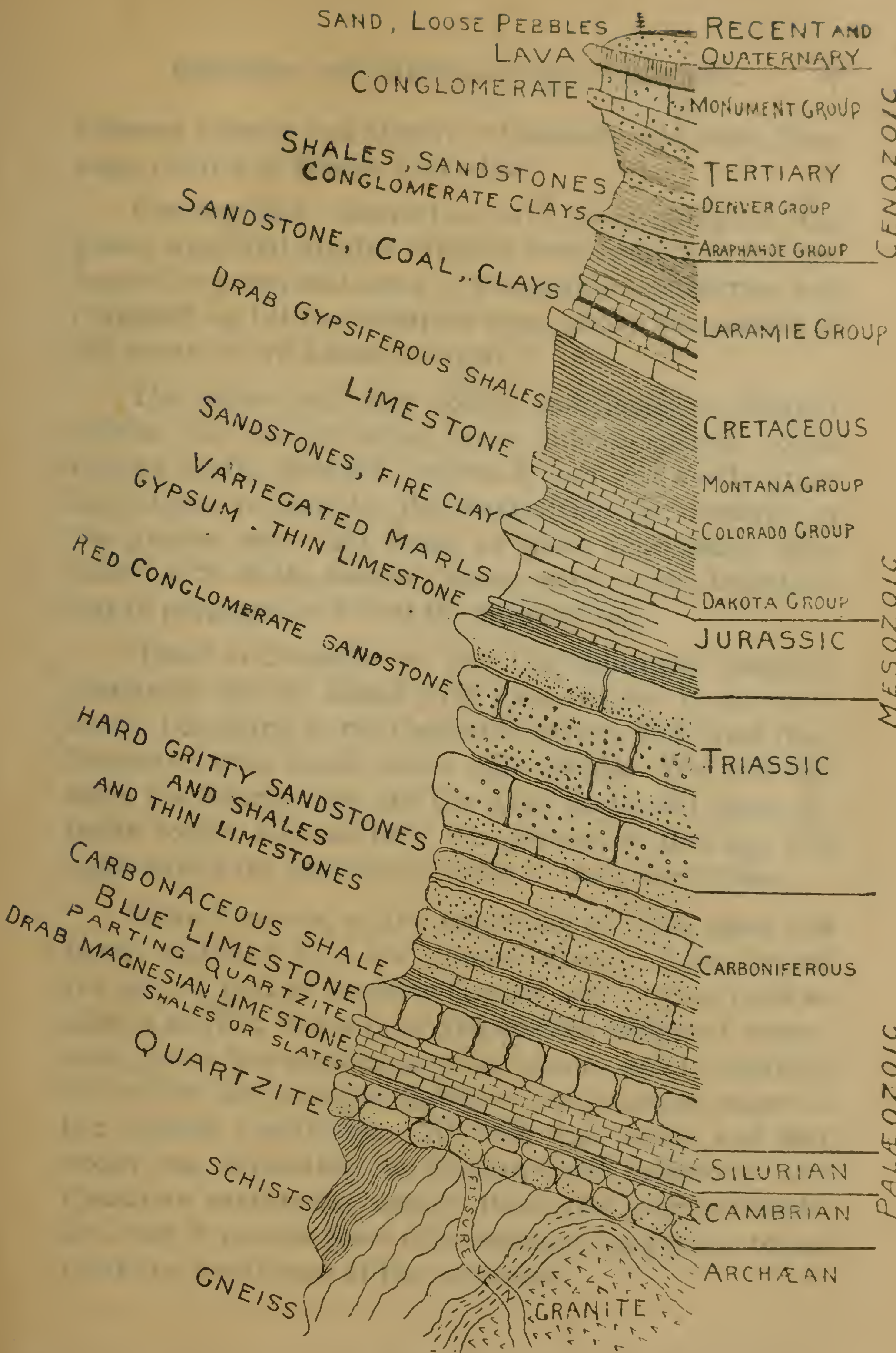
Upon such a surface the gaseous atmosphere gradually condensing descended as hot chemical rain, and filled the troughs of the crumpled surface with a hot chemical steamy ocean. Whatever land of primitive lava arose above this ocean was battered by the waves, reduced to sediment, and deposited as the first stratum in the bed of that primæval ocean, the eruptions from below the thin crust also contributing largely to the same material.

ARCHÆAN AGE.

Thus we may suppose was formed the first stratified rock of the world which we have an opportunity of actually seeing, that is *granite* with its varieties of gneiss, schist, syenite, etc., and as this is the "beginning" age, within human observation, we call it *Archæan*, the Greek for beginning. It would appear that some at least of these granite rocks which form the axes of our mountains are not the very first, because their stratification and composition show them to have been derived from the breaking up of still earlier rocks, which latter may have been the original cooling crust. Some, however, consider the massive granite to have been the original crust, admitting a secondary origin for the stratified gneisses and schists. Others are inclined to consider the whole series as of Plutonic, molten origin, especially the true massive granite.

CAMBRIAN AND SILURIAN AGES.

There are two upper divisions of the Archæan called the Huronian and Algonkian or pre-Cambrian, composed mainly of conglomeratic-gneisses, schists, quartzites and occasionally marble. The pre-Cambrian rocks are shown



VERTICAL SECTION OF THE EARTH'S CRUST IN COLORADO.

PLATE I.

between Ironton and Ouray, in Colorado, and inthe Kootanie district of British Columbia.

Cooling and contraction still progressing on the globe, fresh and greater wrinkles were caused on the surface of its crust, and some of this granite sea-bottom was crumpled up till the crumples arose above the surface of the ocean as low islands or reefs.

The ocean had now cooled sufficiently to support marine life, and so along these granite islands, corals formed reefs, shell-fish swarmed, and sea-weeds grew. Sandstones formed by the waves from the material of the granite were laid down as shore line strata, often mixed with shells, and in deeper water, coral limestone was in progress, as it is at the present day.

Hence in Colorado we find the upheaved crumpled granite of the old island, with its sandstone or quartzite beach, belonging to the Cambrian period, and upon that, limestone, with fossil corals still visible. We call this latter the Silurian age, and the fossil shells and corals Silurian fossils, because they are peculiar to that age and quite unlike the shells and corals of the present time.

North America, at the beginning of these ages, was barely outlined by a few granite islands. One formed the site of part of modern Canada, one or two reefs or islands marked the site of the eastern ranges of mountains, and a few parallel granite islands rudely outlined the site of the principal uplifts or future great ranges of the western Cordilleras. All else was ocean, and that ocean was depositing its Silurian coral limestones and Cambrian sandstones against these few granite islands, destined in time to grow into mountain ranges and to become the backbones of the continent.

DEVONIAN AGE.

Upon the Silurian followed the Devonian, an age characterized by the first land plants and extraordinary fishes. But as it is not generally represented, for some reason, in these mountains, though well shown at Eureka, Nevada, where it consists of reddish limestones and sandstones containing fossil shells and large lead-silver deposits, we pass on to the Carboniferous. These ages we are speaking of are separated from one another by decided and characteristic changes in the fossil animal and vegetable life existing between one age and the other, and in various parts of the world these changes of life are marked also by great geological revolutions such as the elevation of mountain ranges, or great continental masses, and by great unconformity of the rocks.

In America these oscillations between sea and land seem to have been less than in Europe, and we find a general uniform rise of the continent from the ocean and an orderly succession of strata lying against the flanks of the ever-rising granite nucleus of both mountains and continent.

CARBONIFEROUS AGE.

In the Eastern States, as the continent gradually began to rise from the waters, and to the granite islands had been added a Silurian shore, and to that a Devonian shore, a kind of trough seems to have been formed between the middle and eastern part of America, which was occupied by very low, marshy land or marshy islands barely above the sea level. Upon these low-lying lands grew a dense vegetation unlike any of the present day, but resembling somewhat our tree ferns of the Southern States. This low land was subject to freshets from surrounding higher regions which periodically deluged the swamps and its vegetation with river and flood deposits of pebbles and sand, under pressure of which the vegetation was gradually turned into coal. Successive coal beds were formed by successive growths of vegetation between the intervals of periodic inundations, subsidence and upheaval, for these low lands also appear to have occasionally subsided under and been lifted up again above the sea. Finally by a grand revolution which closed the Carboniferous age in America, the coal swamps and strata were crumpled up into the great Appalachian range of mountains. In the Rocky Mountain area the marine condition seems during this time to have been the prevalent one, for we find a predominence of marine limestones and sandstones with very slight indications of coal or land plants.

In Colorado the Carboniferous limestones with fossil corals and shells in them, lie directly upon the Silurian deposits. Upon the limestones come thick beds of sandstone and shale, which latter may mark a land and fresh water state of things, resembling that in the East, for we not only find traces of coal in the South Park range and at Aspen, but also a few fossils of those strange Carboniferous tree-ferns and horsetail rushes or "equiseta." It was not, however, the great coal-bearing age in Colorado as it was in the Eastern States and throughout the world generally. Our great Colorado coal-bearing era is a much more recent one, viz: the Cretaceous.

The Carboniferous, however, contains in its limestones much of our mineral wealth, such as the silver-bearing lead deposits of Leadville, Aspen and other regions.

The Silurian, Devonian and Carboniferous ages have been grouped together into one great division called the Paleozoic time or "old life" of the earth. By Paleozoic rocks then, we mean the rocks of one of these ages, but (in Colorado), only the Silurian and Carboniferous, as the Devonian is missing.

TRIASSIC AND JURASSIC PERIODS.

After the Carboniferous followed the Triassic and Jurassic periods, whose rocks in Colorado are marked by their prevailing red color and consist of heavy bedded red conglomerate sandstones such as may be seen in the gateway of the "Garden of the Gods" at Manitou. In South Boulder cañon, in Platte cañon, at Morrison, in Bear Creek cañon, and almost in every cañon in the foothills, in the Gunnison region and in the neighborhood of Aspen, the same red rocks are very prominent.

In South Park also they are observed on the flanks of Silverheels mountain, and in the neighborhood of Fairplay and the salt works. Besides the sandstones there are thin beds of limestone and variegated clays and marls. The conglomerate sandstones and limestones show no evidence of fossil life, but the variegated marls in the upper portion of the Jurassic have yielded at Morrison and near Canon City some remarkable remains of gigantic lizards called Dinosaurs. It is probable from the presence of salt and gypsum and the redness of the rocks that these red beds were laid down in land-locked salt seas or salt lakes, shunned by animal life.

The upper portions, however, show evidence of low, marshy land and fresh water, by the presence in them of turtles, crocodiles, fresh water shells and Dinosaurs or land lizards. These upper deposits may be of estuarine origin.

CRETACEOUS PERIOD.

After this followed the Cretaceous period, a very thick formation numbering several thousands of feet in

Colorado, consisting in its lower and middle portion of sandstones, white limestones and very thick beds of drab clays. These are mostly marine, as shown by the sea shells found in them. The exception is the Dakota group or Cretaceous No. 1, at the base of the Cretaceous, which, along the foothills forms a prominent "hogback" of white sandstone. In this are fossil impressions of leaves of trees not unlike (but not identical with) those of the present time. The middle or Colorado group of the Cretaceous, consists of limestones and very thick beds of clay, Both limestones and clay contain quantities of fossil, marine shells such as the Nautilus, Ammonite and Inoceramus, the two former resembling a ram's horn or a snake coiled up, the latter not unlike a clam shell.

LARAMIE COAL GROUP.

The upper portion of the Cretaceous is called the Laramie group, and contains our vast and valuable coal fields. Associated with these rocks we find also fossil leaves of semi-tropical vegetation, such as the palm, fig, magnolia, maple, etc. This Laramie group marks an important era in our Rocky Mountains, for it shows the beginning of the great Rocky Mountain revolution by which the granite islands against which all these marine sediments had been forming, were elevated 10,000 feet or more into mountainous masses, dragging up with them portions of the sea bottom and exposing it as land surface, draining off the shallow Cretaceous sea which had hitherto divided the eastern half of the American continent from the western, and bringing on a land and continental condition, which was completed in the following Tertiary age and has continued to the present. The Triassic, Jurassic and Cretaceous are grouped into the Mesozoic, or "middle life" age.

TERTIARY AGE.

The Tertiary age which followed is not so well represented in Colorado as the Cretaceous. It seems to mark an era of comparative rest in mountain elevation, for its sandstones and shales lie nearly horizontally on top of the upturned Cretaceous and other beds. These beds appear to have been formed by wide lakes of fresh water surrounded by tropical foliage. They may be seen capping the Divide between Denver and Colorado Springs, forming the singular "mesa" or table land country, from Castle Rock and Sedalia down to Monument Park and Austin's bluffs, east of Colorado Springs. Also around the Spanish Peaks. From the singular forms cut out of one group of these sandstones by water in Monument Park we call it the "Monument Creek Group." A similar formation is found between Colorado Springs and South Park at Florissant, right in the heart of the Front range. It is a small Tertiary lake deposit, remarkable for its fossil insects, petrified trees and leaves.

In the neighboring territory of Wyoming the Tertiary lake beds form the great Green River region with its fossil mammals, fishes, leaves and insects.

The Tertiary was the world's tropical summer, a period of beautiful lakes and tropical vegetation, but in certain regions it was disturbed by gigantic revolutions which upheaved the Himalayas, the Alps, and other great mountain ranges. Such revolutions as occurred in our cordillera system were marked by frightful ebullitions of lava issuing from cracks and fissures, deluging Idaho, Nevada and part of Oregon and Washington Territory. Remnants of the Basaltic eruptions are found in Colorado, capping our coal table lands along the foothills, particularly toward the southern portion of the State and down into New Mexico. The great lava flows of the San Juan also occurred at this time.

GLACIAL EPOCH.

The Tertiary Summer was closed by the world's great Winter. From causes which we will not here discuss, the ice from the North Pole extended its domain nearly to the Equator. All the northern temperate regions of the world were ice-sheeted, and the sheet extended itself as by long fingers down the now highly developed mountains, filling every ravine with a glacier. It was the Glacial Epoch. In Colorado these glaciers occupied every incipient canon previously begun by streams or by folds in the strata. By their downward destructive movement they widened and deepened the cañons, gouged out the mountains, and exposed the fissure veins, and did the first great mining on a gigantic scale in Colorado. The *debris* they carried on their backs, dumping it at the outlet of the cañons, and when the temperature rose and the glaciers melted, all the long lines of traveling boulders scattered upon their backs were left as banks, or "moraines," or "placer" grounds along the sides of our streams and canons, often a thousand feet above the present river bed, marking the height and thickness the glaciers once attained.

QUARTERNARY AGE.

So were our cañons largely formed and so did our gold placers originate. After the Glacial Epoch a warmer period set in, which we call the Quaternary. The ice melted, vast bodies of fresh water were distributed in wide streams and great lakes over this hemisphere. The rough morainal dumps of the glaciers were sorted or "modified" by water, rolled into pebbles and sand, re-distributed along the banks of streams, and carried out into the beds of the lakes. In these pebbles and sand was much of the precious metal, robbed from the veins. The gold by its insolubility in water remains to this day in our placer beds and "wash," and is collected by sluice or hydraulic mining.

Still the agencies of nature are going on as of yore. Continents are gradually rising or sinking. Mountains are being imperceptibly elevated, water is still sculpturing them with cañons,rivers are carrying down fragments robbed from the land and depositing them in the ocean to form strata for future continents. The fires of the earth are not yet dead, for volcanoes still vomit lava. The earth is still continuing to lose heat, its crust is still contracting and wrinkling itself upward, for we find modern sea beaches raised high on our cliffs. Shocks of earthquakes from time to time prove that motion of some kind is going on beneath us, and doubtless our mountains are still rising imperceptibly, as they appear to have done in the countless ages of the past, and slowly elevating and tilting strata that since the Quaternary period have lain apparently undisturbed. I say apparently, for even the Quaternary and Tertiary beds show often a dip of 2 to 5, and even 10 or more degrees, proving that the mountains have risen that much since these beds were deposited, and that they are probably still rising.

For local illustration of the foregoing, we may descend by the course of any of our streams down its canon in the mountains till it debouches on the prairie. For forty or fifty miles the profound canon is through solid granite or gneiss. The composition of the granite is crystalline. It shows indistinct signs of once having been stratified. Its strata, moreover, show evidence of intense folding and crumpling, as if by lateral, tangential pressure such as would be caused by contraction.

This is the Archæan granite-gneiss that first lay as horizontal sandy strata in the bottom of that earliest, hot and chemical ocean where it was crystallized.

It was then crumpled up into the Colorado-Front-Range island above the Silurian sea, and formed the shore line for ages of seas depositing horizontally the different strata of the Paleozoic and Mesozoic eras.

At the close of the Cretaceous or Mesozoic era it was further crumpled up from an island reef to a mountain range 10,000 to 14,000 feet above the sea level. This movement added new crumples and foldings to its already puckered strata. Heat, due to various causes has partially melted some of its material, which filled fissures caused by the uplift; hence we may find dykes of "eruptive granite," here and there. Heat also seems to have rendered the whole mass of strata more or less plastic.

As we emerge from the granite on to the foothills and prairie we encounter, as we go down the creek, the upturned beds of the various periods we have described, resting at a steep angle against the flank of the granite, in their geological sequence and order. *See plate No. X.*

First are beds of sandstone and limestone, with fossils such as trilobites, crustacea, and spirifer shells, representing the Cambrian and Silurian. Next, variegated beds, with limestone at the base and coarser sandstone and shale near the top. In the latter some traces of coal and coal plants mark its Carboniferous character.

Upon this follows a great thickness of coarse conglomerate sandstones, variegated clays, and some limestone, all of a general red or variegated character.

These represent the Triassic and Jurassic periods, and in the clays of the latter, Dinosaur bones are found at Morrison and Cañon.

A prominent "hogback" or ridge next appears on top of the Jurassic clays. It is formed of hard white or gray sandstone, in which are some leaf impressions. It is the first group or base in Colorado of the great Cretaceous period, and is called the Dakota group, or Cretaceous No. 1.

After we pass this "hogback" we generally find a flat, grassy valley, underlaid by soft, dark shales and clays, full of marine Cretaceous shells, with one or two belts of limestone, also full of large shells. Evidently this is the bottom of the Cretaceous sea, and represents the "Colorado" group of the Cretaceous.

The next uplifted sandstone we meet with shows seaweed fossils in it, and a little higher up, land plants, and then two or three coal beds. This is the uppermost group of the Cretaceous, known as the Laramie coal series.

A few scattered table mountains of horizontal strata, with fossil leaves, may locally be met with, as on the Divide, which represent our Tertiary period. And lastly, on top of all these strata, both horizontal and upturned, we find scattered over "hogback" and prairie alike, the drift or "wash" of pebbles of all kinds, distributed by the glaciers and floods of the Quaternary.

Thus since we left the granite at the outlet of the canon we have passed through and examined not less than 10,000 feet in thickness of the crust of the earth, comprising all the periods from Archæan to Tertiary and Recent. We have found the strata of the several periods and epochs lying upturned against one another, like leaning rows of books, till we come to the top of the uppermost Cretaceous or Laramie coal, and then the Tertiary lies flat, or at a gentle angle. We conclude, then, that the strata of all these periods and epochs were accumu-

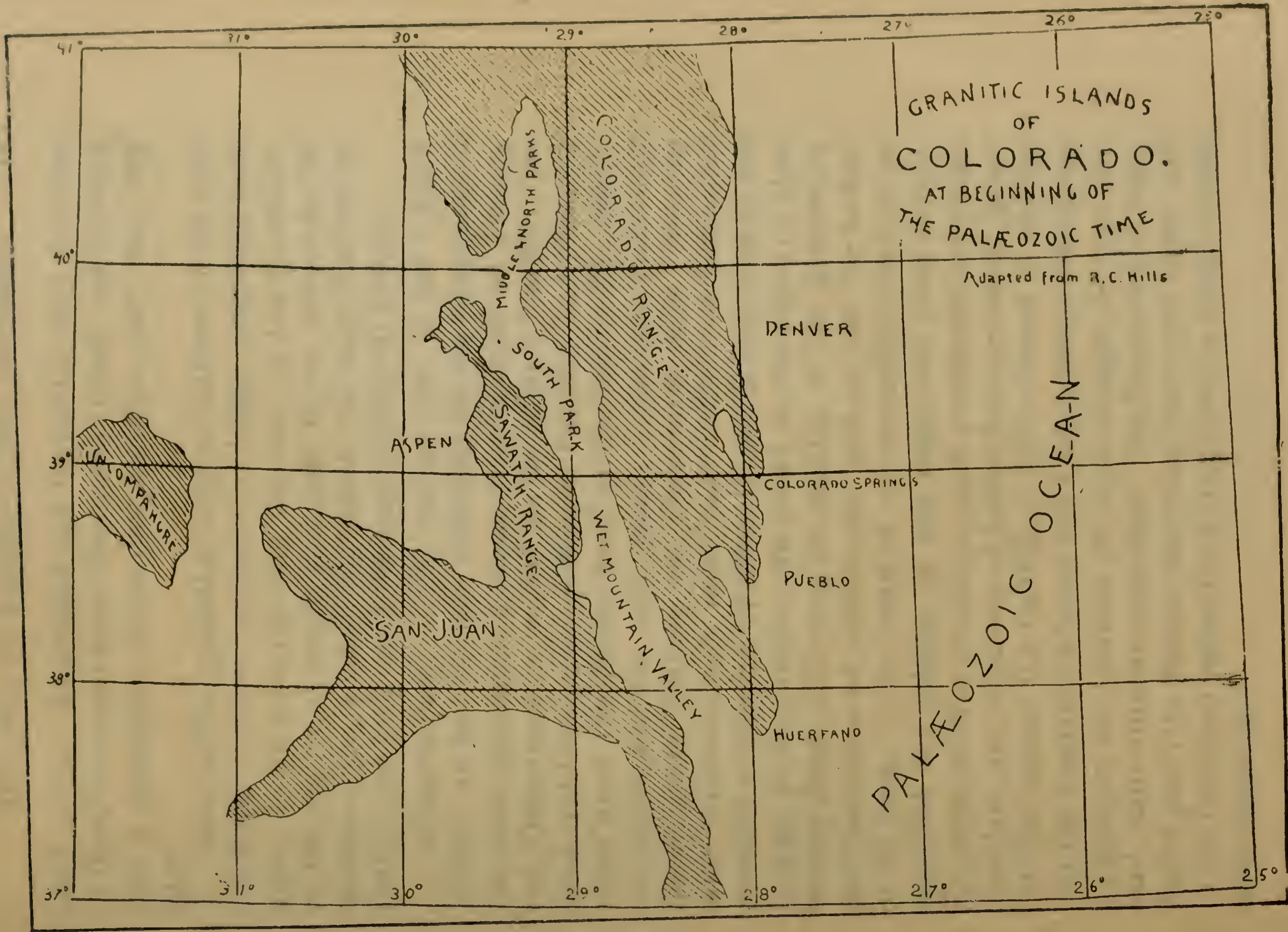

GRANITIC ISLANDS
OF
COLORADO.
AT BEGINNING OF
THE PALÆOZOIC TIME
Adapted from R. C. Hills
UNCOMPAHGRE
ASPEN
SAN JUAN
SAWATCH RANGE
SOUTH PARK
MIDDLE & NORTH PARKS
COLORADO RANGE
WET MOUNTAIN VALLEY
DENVER
COLORADO SPRINGS
PUEBLO
HUERFANO
PALÆOZOIC OCEAN

PLATE II.

lated and lay undisturbed and horizontal until the close of the Cretaceous, when the granite island was elevated into a mountain. Since then elevation has been very slow

Such are the general geological features of the eastern slope of these mountains and their attendant foothills. If we penetrate into the heart of the mountains, to the region of South Park, and thence across to the western slope, we shall find much the same features repeated, and with much the same geological history.

In South Park, on the western side of the "Front Range," we find its basin underlaid by the same rocks of the same geological periods, from Silurian to Tertiary and Quaternary, as we find on the Eastern foothills; the same Post-Cretaceous uplifting of Paleozoic and Mesozoic rocks upon the flanks, even to the top of the granite mountains, and the same pause in elevation marked by the horizontal Tertiary and Quaternary beds. Also the same evidences, only much more distinct, of the former presence of glaciers, by moranial placer beds, and by the U shape of the canons, with marks of the action of Quaternary floods, following the melting of the glaciers, in the distribution of pebbles and sand all over the surface of the park. In the heart of our mountains, however, we find that the folding of the rocks was more violent. Eruptions of lava incident on such movements were more abundant, and evidences of former heat are more apparent than nearer the foothills. This is shown in the fact that the unaltered Silurian and Carboniferous sandstones we meet on the foothills, are here changed by heat into hard, white vitreous quartzites. The limestones in many places pass into marble, shales and clays into slates, and in the Gunnison region the Laramie coal is locally turned into Anthracite.

The Colorado "Front Range" and the Sawatch Range each being surrounded by the same set of marine and other strata, shows them to have had the same history; first as horizontal granitic strata, next lifted into granite islands in the Cambro-Silurian ocean, and lastly, at the close of the Cretaceous, elevated into mountain chains carrying up with them the various beds so long accumulating in the seas by which they were surrounded.

With these preliminary explanations, the following epitome of a sketch of the general geological history of these mountains, from the accurate observations of the U. S. Geological survey, will be intelligible.

At the close of the Archæan era, when the earth was covered by a Silurian ocean, a large area covering most of what is now the Colorado, or "Front Range," formed a large rocky granite island, with a number of smaller islands lying to the west of it, the most important of which now forms the Sawatch Range from which it was more or less completely separated by the sea waters occupying the present depressions of the North, South and Middle Parks. During the whole of the Silurian, Carboniferous, Triassie, Jurassic, and Cretaceous periods, *i. e.*, the Paleozoic and Mesozoic times, a continuous deposit of sediment went on in the seas surrounding these islands, of materials such as sand and pebbles washed from these granite islands, and also of organic limestone derived from corals and shells.

No great disturbances took place throughout this long period, hence all the different strata with their various fossils lay for the most part conformably and horizontally one on top of the other in successive order.

Toward the close of the Cretaceous period, that is, at the end of the Mesozoic, at the time of the formation of the coal beds, the seas became shallower, owing to a general elevation of land, and considerable portions of the outlying area were partially enclosed. During this time and possibly earlier, immense masses of eruptive igneous rock were forced up through the already deposited sediments still lying horizontally beneath the waters.

Unlike the lava flows of modern days, these molten masses did not spread out on the surface of the rocks, but congealed before they reached that surface either in large masses, in dykes or in sheets spread out between the strata. These phenomena are well exhibited in the Leadville, Gunnison and Aspen districts.

We do not know how long before the Cretaceous the eruptions of these igneous rocks commenced, but they certainly continued to the close of that period, for we find them traversing rocks of that age—as at Crested Butte, Irwin, and Gothic, in the Gunnison region.

Some time after the close of the Cretaceous a general upward movement took place in the Rocky Mountains, by which the existing mountain ranges or islands were crushed together, broken and elevated, and considerable areas of the adjoining sea bed were lifted above its surface.

In the general continental elevation which followed duing the Tertiary period, fresh water lakes or enclosed seas were formed, in which, by the washing away of the newly made land areas, considerable sediments were deposited, such as the strata on the Divide and at Florissant, and the table land country generally.

During this Tertiary era and after it, eruptions of lava also occurred, generally following the lines of earlier and older eruptions, but unlike the latter, spreading out on the actual surface of the land, and in some cases beneath the sea, as for example, the basaltic cap of

"Table Mountain" (Golden), Fisher's Peak, near Trinidad, and the rhyolite capping of thé mesas of the Divide.

While the general form of the mountain area was sketched out and determined in the earliest geological times it is only since the Tertiary, and in a great measure by erosion after the Glacial epoch, that the present sculpturing of the mountain forms with their ravines and cañons has taken place.

GEOLOGICAL AGE OF MINERAL DEPOSITS.

At what period the different mineral deposits of Colorado were formed cannot be definitely stated.

The gold deposits of Gilpin County may have been during or after the Archæan age, since they occur in Archæan rocks, but as in the immediate vicinity of these deposits there are no later rocks to limit their exact age, they may have been before the Silurian or very much later.

The silver-lead deposits of Leadville were certainly formed after the Carboniferous, and before the mountain upheaval at the close of the Cretaceous, because in the first place, they penetrate Carboniferous rocks, and in the second place, the fissures, faults, etc., formed at the time of the Cretaceous uplift, cut through and fault these deposits.

Those of the Gunnison region are later than the Cretaceous, because they occur in fissure veins, cutting through the Cretaceous rocks, even through the Laramie coal beds.

Those of Custer and San Juan were probably formed in the Tertiary, because they traverse andesites and other lavas of "presumably Tertiary age."

CONNECTION BETWEEN MINERAL BELTS AND MOUNTAIN UPLIFTS.

In the greater Cordillera system, of which our Rockies are a part, there appears to be a definite connection between mineral belts and well-known lines and times of uplift. There are several well defined, more or less parallel mineral belts in the Cordillera system.

There is one at the foot of the Wahsatch Mountains, represented by the Utah mines, which lie in the foothills of this range with a definite relation to the main line of crests.

The gold and copper belts of California stand in a similar relation to the Sierra Nevada.

The quicksilver and cinnabar belt of California is a belt parallel to the Coast Range.

The Arizona belt lies in a northwest and southeast direction diagonally across the country.

The mining districts of Nevada cannot be so easily grouped.

Now these four distinct belts are connected with four great mountain building changes and uplifts, which the region west of the Rockies have undergone.

The last of these was after the Miocene Tertiary, resulting in the uplift of the Coast Range, together with part of Oregon and Washington Territory. The disturbing force was most powerful north and south of San Francisco, and there lies the cinnabar belt. An upheaval soon after the Cretaceous, raised the whole western-central portion of the continent, now occupied by the complicated system of the Rocky Mountains.

The Wahsatch Range is the western edge of this uplift, and the dislocation took place on an old fault, coincident with the present western foot of that range, and here, as we have said, lie the mines of Utah.

The Sierra Nevada and ranges of the great basin were raised by an uplift at the close of the Jurassic.

The line of most intense disturbance coincided with the Sierra and the greatest dislocation occurred along its western foot in what is marked by the gold belt.

The earliest disturbance in the far West was that which raised the Paleozoic strata of Eastern Nevada, Western Utah and a part of Arizona above the surface of the ancient sea, extending over part of the plateau and Colorado river region, past Prescott and on to Tombstone, Arizona. The main Arizona belt nearly coincides with the borders of the Paleozoic uplift.

The age of mountain uplifts we judge by the strata involved in that uplift, thus we know that the great uplift of the Rockies occurred at the close of the Cretaceous, because both the Cretaceous rocks and all those of previous ages are uptilted with the mountains while the Tertiary rocks are not so severely tilted.

These uplifts are not the immediate cause of mineral belts, but rather of fissuring and faulting.

The uplift in Nevada, at the close of the Carboniferous, was gentle, without much crumpling of rocks, hence the number of ore deposits is not so great along its edge; those we do find, however, such as at Battle Mountain and Cerro Gordo, are on the edge of the uplift, and are rudiments of the belt, better defined in Arizona, where the uplift was more violent.

Thus there appears to be a relation between ore belts and lines of uplift, from which we may infer that the great Post-Cretaceous uplift of our Rockies determined some of the lines of our ore belts, and we shall find the line and time of uplift of some of the minor ranges in Colorado more or less coincident with the mineral belts found in them.

The uplift of a great range is not along a single line of dislocation, but such movements are accompanied by a great number of parallel faults, and parallel sets of fissures, with stringers running off into the surrounding region. A large belt of country is fractured by innumerable rents in many directions, which may afterwards be filled by veins, and constitute a mining district.

PRINCIPAL ORE-BEARING ROCKS.

In Colorado gold is found mainly in the Archæan granites, gneisses, and schists, and also in the eruptive porphyries of Mesozoic or older age, and in the placer beds derived from these rocks.

In sedimentary formations, it is rare in limestone but occurs in quartzites of Cambrian, Silurian or Carboniferous, and locally of Cretaceous age.

Silver is found in the Archæan and in the porphyries, and occurs especially in the limestones of Carboniferous age, as also in those of the Silurian, and locally in some of the Cretaceous Rocks.

The most important ore deposits are found where igneous eruptive rocks abound, especially in rocks of older date, as porphyries, rather than in the newer Tertiary volcanic rocks, such as basalts. Locally some important ore deposits occur in Tertiary andesites and rhyolites.

The "hogbacks" along the foothills consisting of upheaved limestones, clays, shales and sandstones yield no precious metals, and it is only when the mountains have been penetrated to their core that precious minerals are found productively.

The mineral deposits of Boulder are the nearest to the "hogbacks" and plains in this respect, some of the mineral belts being only two miles distant from the foothills.

Though the sedimentaries forming the "hogbacks," foothills and plains are not found productive, yet in the heart of the mountains where foldings, crumplings and volcanic eruptions have occurred, we find the same rocks quite prolific in minerals; notably in the Gunnison, South Park, Aspen and Leadville districts.

PART II.

COLORADO ORES AND THEIR MODES OF OCCURRENCE.

Metals occurring in a nearly pure state are called "native." Native gold in Colorado is sometimes visible to the eye in the form of little hairs or wires, or as minute grains or thin flakes upon a piece of ore, quartz or rusty material, but very rarely as nuggets in a vein. Nuggets, together with fine flakes of gold, are found in the gold placers. Native silver also occurs in little bunches of wires, and is sometimes called "wire silver." It is also visible as flakes or strings in vein matter. Native copper is occasionally found in thin plates in crevices of the rock. Metals united with non-metallic substances form "ores" proper. Most of our precious metals in Colorado are found in this condition. Metals unite with non-metallic bodies, as sulphur or chlorine, forming sulphides, (ex. gr. iron pyrites or galena,) or chlorides, such as horn silver; with oxygen, forming oxides, as oxide of iron or of manganese; with acids and salts producing carbonates, sulphates, etc., for example: carbonate of lead, (cerussite,) sulphate of lead, (anglesite,) carbonate of copper, (malachite,) carbonate of iron, (siderite).

Any material containing a workable proportion of a metal is commonly called an "ore." For example, quartz carrying gold-bearing pyrites, or limestone containing silver-bearing galena. Ores are found in surface deposits, such as gold in placers, disseminated through igneous eruptive rocks, such as porphyries, also through sedimentary rocks, such as limestones, between stratified formations, such as between layers of quartzite, limestone, or gneiss, and in veins of different kinds, traversing all kinds of rocks.

The non-metalliferous and earthy minerals associated with the ore, such as quartz, calcspar, baryta, are called "matrix," "veinstone," or "gangue."

GEOLOGICAL OCCURRENCE.

Metals occur in Colorado in rocks of every geological age, principally in the mountainous districts and in the older rocks, especially at the junction of igneous eruptive rocks with sedimentary rocks.

The Archæan age is represented by the veins of Georgetown, Central and Boulder.

The Silurian and Carboniferous by the ore deposits of Leadville and South Park.

The Triassic by some copper stains in various localities, and a few lead deposits.

The Cretaceous by the Ouray Gold Belt, the veins of Crested Butte and Gunnison, and by iron-ore deposits.

The Tertiary, by the veins in the Tertiary eruptive rocks of the San Juan region of Cripple Creek and Silver Cliff.

The Quaternary by the various placer deposits.

The Archæan, Silurian and Carboniferous, *i. e.*, the older rocks, are the great ore producers.

The plains and foothills yield no precious metals, only a few base ores, such as iron. The precious metals are mostly confined to the heart of the mountains, and diminish in occurrence as we recede from it.

The ore deposits of Leadville occur at the junction of eruptive quartz-porphyry with limestone. Those of Georgetown, Central and Boulder are also frequently found at the contact between porphyry and gneiss.

Metals also occur in sedimentary rocks which have been penetrated by dykes of eruptive rock, or have been exposed to great metamorphism. The Gunnison region around Crested Butte, Gothic and Irwin is a good example.

The marine Cretaceous sandstones and limestones and the Laramie Cretaceous coal strata have there been locally riddled by dykes and volcanic masses, which, besides throwing the region into strange contortions, have also, by their heat, metamorphosed it, changing limestone into marble, sandstone into quartzite, shales into slates, and coal into anthracite.

In this region veins of silver, lead and other ores are found, showing the striking connection between heat and its attendant metamorphism with vein occurrence.

ORES FAVORING PARTICULAR GEOLOGICAL HORIZONS.

Ores seem to favor some particular geological horizon, not because that particular geological age or horizon was one especially productive of mineral at the time of its formation, but rather that the rocks of that age happen by peculiar circumstances to be better adapted for *receiving* mineral solutions than those of some other ages. Thus the "blue limestone" of the Lower Carboniferous throughout our mountains has been particularly productive, not because it belonged to the Lower Carboniferous age so much as because it is locally penetrated by eruptive rocks, the limestone itself being favorable for *receiving* mineral deposits. Where the eruptive rocks do not occur the Carboniferous limestone is commonly as barren as other limestones generally are in Colorado.

GOLD PLACERS.

Gold is found in surface deposits of sand and pebbles resulting from the breaking up of older rocks by glaciers, and the distribution of the detritus by rivers, in what we call "placer ground" or gulch mines. Among the pebbles and sand, gold is found in flakes and nuggets. The gold is derived partly from broken up gold-quartz veins in these older rocks or from the disintegration of the constituent minerals composing the mass of the rocks themselves, which contain minute particles of gold in their elements, particularly the igneous or metamorphic rocks, such as porphyries and granites. These placer deposits are of recent origin, dating from the Tertiary or Glacial Epochs to the present, and are to be found in nearly every mountain ravine in Colorado, or on the banks of our principal streams.

Those at Alma (South Park), along the Arkansas valley, and at San Miguel in the San Juan country may be cited as examples.

Platinum and tin are found under similar conditions, but these metals do not occur in Colorado.

NATURE'S MILLING PROCESS.

Gold quartz from a vein requires its gold to be artificially separated, first by crushing and next by water, the heavy metal sinking to the bottom, the lighter veinstone being carried off by water. In the case of placers which consists of boulders, pebbles and sand on the banks of streams or sides of canons, representing specimens of the varieties of rock over a large area, nature has already performed this process on a grand scale. The glaciers have mined and torn off the gold-bearing quartz of the veins together with cubic miles of rocky material, also holding minute portions of gold disseminated through it. The streams have reduced this to pebbles and sand, have mechanically separated the gold, and also probably by the action of acids chemically set it free from other minerals in which it was contained. By its gravity it sinks to the bottom and is found in greatest quantities next to the "bed rock" in cracks and crannies. The miner, after all this crushing, concentrating and jigging by nature, has only to re-wash and sift the *debris* and collect the water-worn flakes and fragments of free gold with or without the assistance of quicksilver.

CALIFORNIA PLACERS.

The vast placers of California lie for many square miles on the hills of the Pacific slope of the Sierra Nevada. They are called "blue gravels," and were brought from the range by glaciers and distributed over the more level country by ancient rivers and by lake-like expansions of such streams. The fossil remains of elephants and plants in them show them to date from the Tertiary or Quaternary age. Afterwards these river deposits were covered by volcanic ashes issuing from eruptions in the Sierras and finally by streams of lava from the same source. This hard molten crust upwards of one hundred feet thick, protected the underlying gravels from being washed away. Chemical changes in these gravels have silicified and changed to opal the once water-logged tree trunks brought down in these gravels. Some have been changed into lignite coal before silicification, part of the wood resembling jet, and part opal. The gravels are also cemented by silica. Stone implements have been found under 100 feet of lava in the gravels, showing man's existence at the time the gravels were deposited. There are also several uncovered placers worked by hydraulics. Rivers flowing through the gold belt of California have acted as natural sluices of which the miner's sluice is a diminutive copy, the upturned slates acting as "riffles" to catch and retain the gold. The Australian placers are very similar to those of California.

COLORADO PLACERS.

The placers of Colorado have the same history, with the exception of the lava capping. The glaciers of the Glacial epoch and the floods resulting from their melting in the Quaternary epoch have been the main distributers of our placers. The gold is doubtless in part derived from gold-bearing quartz veins and gold-bearing rocks higher up on the mountains than the placer beds. Thus the placers of Clear Creek derive their gold from the veins and gold ore-bearing region around Central, Idaho Springs and Georgetown. The placers at Alma and Fairplay, South Park, from the veins and eruptive rocks near Mt. Lincoln and Montgomery, and the park ranges. The Tarryall placers in the basin of South Park from the auriferous deposits lately discovered in the eruptive rocks in the mountains above Breckenridge. The rich placers in "California gulch," now occupied by Leadville, and those widely distributed through the broad valley of the Arkansas, may have derived their gold largely from disseminations in the metamorphic granite, and particularly in the eruptive porphyrics, as gold veins have not so far, been discovered in great abundance in that characteristically lead and silver bearing district. Some rich gold veins have lately been discovered near Twin Lakes in the Sawatch range.

COLORADO PLACERS DUE TO GLACIERS.

It is noteworthy that each of these localities show unmistakable signs of former great glaciation. Clear Creek had its great glacier descending from Georgetown and joined at the forks of the creek by one coming down from Central. The whole valley in which Alma and Fairplay are located shows similar signs of a great glacier descending from back of Mt. Lincoln and receiving tributary glaciers from Mosquito, Buckskin and other canons. The basin of South Park was occupied by a glacial lake into which glaciers descended from the mountains around Breckenridge. The Arkansas valley was filled by a prodigious glacier receiving innumerable tributary glaciers from the canons of the Sawatch and from the slopes of the Mosquito Range.

Upon the moderation of temperature and consequent melting of these bodies of ice the Arkansas valley was occupied by a broad river, and "lake-like enlargements" of the same, which distributed the placer drift and gravel in banks and terraces over that area. That gold may be derived from the breaking up of igneous rocks seems probable from the "black sands" of the California sea-beaches which consist of titanic iron derived from the breaking up of the eruptive rocks of that volcanic region. These sands carry small nuggets and fine gold dust, the latter often too fine to save by present processes.

TIN.

Platinum and tin are found in other countries, but not in Colorado. Specimens of "stream tin" in dark brown, round nodules of the variety called "wood tin" showing a banded, jasper-like structure are found in the drift material in Durango, Old Mexico, but they have never been traced to any vein. So far as the geological relations are concerned there seems no reason why tin might not be found in the Archæan granite rocks of Colorado. In England it occurs associated with granite, porphyry dykes, slates and quartz veins. The English "stream works" are placers derived from these in the same way as our gold placers are derived from rocks originally "in place."

CHARACTERS OF GOLD IN PLACERS.

Nuggets of a large size are not common in gold veins, as they are in placers, yet they may exist in veins, for the largest American nugget, according to Newberry, was found in the vein of the Monumental mine at the Sierra Buttes, Downsville, California. It weighed ninety-five and a half pounds. Possibly in times long before man or mining, they may have been more common in the veins than now. And again, as our mining operations are but slight, they may be found hereafter.

Gold in placers is pure and of higher grade than that in veins, owing probably to its having been leached of its alloys by water and chemical action.

Silver we do not find usually in placers, it having been destroyed by water, but such insoluble substances as magnetite, titanic iron, garnets, rubies and even diamonds are found closely associated with gold in placers.

Gold is not wholly insoluble, but may be attacked by persalts of iron and salts of vegetation, so it may go through some chemical changes in placers, and some nuggets may possibly be formed by concentration of gold in the placer itself. Nuggets of large size are, as a rule, found nearest the quartz veins which have supplied them, and the gold becomes finer as we recede from the source of the mountain region. Pebbles of quartz containing gold are common in placers, showing the origin of the gold from a quartz vein, sometimes at least. Nuggets show on their surface the battering they have received in the stream.

CHARACTERISTICS OF PLACERS.

"Placers where water currents were broken by a more moderate descent, sudden change of direction, or discharge of a side stream, are liable to receive gold deposits. Slight depressions, holes, open fissures or cracks in 'bed-rock' over which the current passed are often rich. The deepest layers near the bottom of the placer deposit or on the 'bed-rock' are generally richest. Periods of deposit may have followed one another and several rich layers lie one above another. Ancient as well as modern river channels may contain gold." The prevalence of a certain peculiar or characteristic pebble in a placer may enable one sometimes to trace the gold deposit back to the original locality whence the placer was principally derived and so lead to the original vein.

In some localities, especially where the "bed-rock" happens to be jointed sandstone or limestone, the gold may find its way for some little depth beneath the strata, and it becomes necessary to remove carefully a few feet of the bed-rock until a true "floor," such as an impervious layer of clay or other rock is found, below which experience proves the gold does not pass. The richest deposits of gold will often be found on that floor. The placer beds in Colorado consist of banks of pebbles of all sizes, mingled with some sand and gravel, showing little or rude signs of stratification. These beds are from 10 to 50, sometimes 100 feet thick and form a series of rolling or undulating banks along the sides of our canons, valleys or watercourses. Gold is found from the grass roots to the bottom of the deposit, but principally near the bottom, and especially on "bed-rock." Associated with the gold, usually near the bottom of the bank, we often find a rusty sand containing pebbles of magnetite iron known as "black sand." This iron may have been derived from the original pyrites or "blossom" of the gold vein, and been changed chemically.

SURFACE DEPOSITS.—BOG IRON.

Of other surface deposits the commonest are those of bog iron, with which manganese oxide is sometimes associated. These beds, which are more or less impure, consist of hydrated peroxide of iron containing, when pure, 14.42 per cent. water. Phosphoric acid is sometimes present in quantity sufficient to diminish its value as an iron ore. Too much silica and other impurities may have the same effect. Bog iron ore frequently encloses the partially fossilized remains of roots of trees and swamp vegetation. The ore is the result of the chemical action of water, assisted by the acids of vegetation, upon minerals containing iron in another state, as upon iron pyrites and copper pyrites, as seen in the brown "gossan," "blossom" or "float" of the outcrop of veins. Iron-bearing minerals such as mica, hornblende, and augite, common in granite and eruptive rocks, contribute to these ores.

A deposit of bog iron ore is found near Crested Butte, in a swamp situated upon a terrace or drift at the base of a mountain. The original source of this iron is traceable to a vein of iron pyrites up the mountain slope. The drainage of the mountain has passed through this vein, leached out the iron from the pyrites, and redeposited it in an oxidized and hydrated state in the swamp. The acids of the marsh vegetation have assisted in this chemical change, and in the precipitation of the iron, which is found enclosing the roots of trees and grasses. The ore is remarkably good and pure. Its amount of Phosphoric acid is too high for Bessemer steel, but not for common pig iron. The amount of silica is very slight, while its percentage of peroxide of iron is very high.

Analysis by Professor Chauvenet, of School of Mines:

Water and organic matter	23.97	per cent.
Silica	2.50	"
Peroxide of iron (iron, 50.73)	72.47	"
Alumina	0.28	"
Lime	0.22	"
Magnesia	0.12	"
Phosphoric acid	0.333	"
Phosphorus	0.145	"
Total	99.893	

IRON ORE IN COLORADO.

Iron ores, when they occur in metamorphic crystalline rocks, such as granite, are in the state of ferric oxide (hematite), or magnetite. These ores are found in metamorphic rocks of Archæan and Paleozoic age.

Red hematite may be crystalline, fibrous, botryoidal, or compact. Magnetic iron ores containing much titanic acid are valueless. The magnetite from Grape Creek, near Silver Cliff, is an example. Fine-looking magnetites from several localities in Gunnison County are of no value, from their high per cent. of titanic acid. The black auriferous sands of California derived from the breaking up of eruptive rocks are titanic.

"Magnetite" was originally deposited by water solutions as a common hydrated iron or limonite, and by heat of metamorphism was crystallized like the surrounding rocks into magnetite, in this way losing its combined water.

In the oldest rocks, and especially the crystalline rocks, such as granites and porphyries, iron is a constituent of many of their component minerals, such as hornblende, garnet, mica, augite, etc. It is also the staining element in our feldspars, giving them their pink or red tint. In such rocks the ore is generally magnetite when in granite, and hematite when in schist. Much of the common limonite and iron oxide found in unaltered sedimentary sandstones along our foothills and plains was indirectly derived from these sources, for the elements of these unaltered sandstones consist of the detritus of granite and other older crystalline rocks when the sedimentary rocks were in the condition of gravel or soil. The magnetite and hematite in the granite minerals being exposed to water, were changed into hydrated ferric oxide. In this condition as a red coloring of the soil it was exposed to carbonic acid and the acids of vegetation, and was finally deposited as a common limonite, or as a carbonate of iron ("kidney iron stone.")

From observations in some of our iron veins in Colorado it would appear that iron pyrites is the original form from which by a secondary process, principally through surface action, magnetite and probably red hematite were derived, for we find magnetite on the surface passing down with depth into a vein of unaltered iron pyrites. "The process may be thus: iron pyrites under surface action has its iron and sulphur oxidized, and passes first into iron sulphate and thence into iron oxide. If heat or metamorphic action should now take place it is crystallized or changed into magnetite or red hematite."

As limonite and some carbonate of iron is so characteristic of the unaltered sedimentaries of our plains and foothills, and magnetite and hematite of our metamorphic rocks of the mountains, we might consider the latter as metamorphic iron. Magnetite is the best and leading ore of Colorado at present. From Professor Chauvenet's report we learn that—

"The only ores of iron available for manufacture of pig metal are the oxides and carbonates, the latter being very scarce in Colorado.

"Often a great deal of work has been done on deposits of no value which could have been obviated by a slight analysis previous to the undertaking. We may consider then what constitutes a good iron ore for pig metal.

"1. *Iron*—Ores containing under 50 per cent. are generally valueless, with the exception that if an ore be high in its percentage of water with little over 50 per cent. iron (Limonites and brown Hematites), by roasting its water can easily be expelled. The roasted ore is then rich enough for smelting.

"2. *Silica*—Ores assaying 15 per cent. or over can rarely be used to advantage. If 20 per cent. or over it amounts to a condemnation. Under 10 per cent. is a usual demand and under is an exceptionally favorable figure.

"3. *Phosphorus*—No ore of iron is entirely free from this element. It may be present in quantities not exceeding 0.05 per cent. in an ore which is to be used for the manufacture of Bessemer metal, but for ordinary purposes its percentage may vary from this low amount up to as high as 0.5 per cent. or in a few cases even higher. 'Scotch pig' is ordinarily very phosphatic, some grades running as high as 2 per cent. in phosphorus. It confers fluidity and enables the founder to use a large per cent. of 'scrap' in his mix.

"4. *Sulphur*—Objectionable in all quantities, big or little. Ores containing over 1 per cent. have to be roasted previous to being charged. The influence of sulphur on iron is always bad, no matter for what purpose the metal is to be used. In this it differs from phosphorus, a small percentage of which, however objectionable in metal intended for Bessemer steel, is rather desirable in certain quantities of pig metal.

"6. *Manganese*—Generally considered a favorable constituent in small quantities in an iron ore. When the percentage gets to be very high, it can be no longer considered as an iron ore, but assumes a special value, as will be shown later in the description of Gunnison county menganese ores.

"7. *Lime and Magnesia*—In small quantities these elements cannot be said to be at all injurious. Of course if the percentage rises to a high figure it diminishes the richness of the ore, as would any other impurity.

"8. *Titanic Acid*—This is one of the curses of the furnace when in any quantity. It is reported that some French founders have found it very practicable to use ores of late which contain considerable amounts of it. However, no furnaceman in this country would knowingly charge a mix containing over 4 per cent. of it, and even 2 per cent. has been found to be a decided detriment. It would seem that this is entirely owing to its effect on the tonnage yield of the furnace, and the extra fuel required, since it has not so far as I am aware ever been claimed that the quality of the product is injuriously affected.

"The conditions necessary for manufacturing cheap pig metal are:

"1. Abundant ore running 55 per cent. of metal at a low cost of mining.

"2. Coking coal low in ash and sulphur; minable in large quantities.

"3. Pure limestone.

"4. Reasonable proximity of all the mixed products to the furnace site.

"5. A scale of wages bringing item of 'labor per ton' inside of $2.00.

"Gunnison County seems particularly favored in these requisite points as regards material, etc."

Along the foothills, beds of concretionary iron-ore occur commonly above or below our coal seams of the Laramie Cretaceous. It is generally a limonite running too low in iron and too high in silica and phosphorus to be of use. So far no promising iron beds along our plains or foothills have been discovered of much value.

At the Trinidad coal field several thick belts of concretionary iron ore occur above the coal seams under Fisher's Peak. The ore appears to be partially oxidized carbonate. Its analysis shows silica 9.19 per cent., protoxide of iron 45.04, lime 4.02, phosphoric acid 1.055, carbonic acid 33.035. Probably this is a type of other deposits along the coal strata of the foothills. "Such ore might be used for smelting common pig iron. Its phosphorus percentage is too high for steel, but it might be utilized as a mixing ore."

The marine dark shales of the Fort Benton group of the Cretaceous, that is Cretaceous No. 2, yield locally, near Morrison and elsewhere, some dark heavy concretions, whose percentage of iron, not over 22, is too low for use, its silica being also high. It is to the mountain region we must turn for our great iron deposits. At Villa Grove we find irregular deposits of brown hematite in the metamorphic, Paleozoic limestones yielding 58 per cent. iron, with only 0.031 phosphorus and no titanic acid. This is a good Bessemer steel ore.

The Calumet mine in Chaffee County is one of the best in Colorado. It is a great vein 40 feet thick, traversing syenitic, crystalline rocks, and yields 63.28 per cent. iron, with only 0.016 phosphoric acid. It is largely used at the Bessemer Steel Works. In Park County, on Silverheels Mountain, near Breckenridge, a vein which produces excellent magnetite on the surface appears, with depth, to pass down into original iron pyrites, giving by analysis:

60.40 peroxide iron.
22.12 protoxide iron.
5.9 silica.

No phosphorus and no titanic acid. This vein appears to illustrate what we have said of pyrites being the original mineral from which magnetite is derived.

GUNNISON COUNTY IRON MINES.

Perhaps the heaviest deposits of magnetite yet found in Colorado are in Gunnison County. Of these the "Iron King," near White Pine, is the most striking, owing to its great outcrop and partial development.

The most important iron deposit so far developed in Gunnison County is known as the Iron King, situated close to the mining village of White Pine, twelve miles from Sargent, on the Denver & Rio Grande Railway, and within forty-five miles of Gunnison City.

The deposit is of extraordinary magnitude. The outcrop is enormous, high in grade and extends at intervals for a mile on the mountain side. Near White Pine a tunnel has been driven, cutting across the vein, but not at right angles to its course. This cut is ninety feet in length, all in ore, but if cut at right angles to the walls would have shown about seventy feet. Of this I estimate forty feet to be minable "en masse," while from the remaining thirty large quantities of good ore could be taken by selection. Streaks very well defined of quartz run through portions into the best of the vein. The deposit is Paleozoic, probably Silurian strata. It lies between quartzite and limestone, and averages best in grade and solidity nearer to the latter. The ore is a magnetite without pyrites, very little sulphur, whilst phosphorus is

so low as to class the ore at once as a Bessemer material. Titanic acid is absent, showing the ore to be remarkably pure and good. The analysis shows—

Water	0.65	per cent.
Silica	3.85	"
Iron (metal)	58.75	"
Phosphorus	0.044	"
Sulphur	0.123	"
Lime	trace.	
Magnesia	none.	

Six hundred tons from this deposit yielded at the smelter 66.42 per cent metallic iron. An average of 60 per cent could easily be obtained.

The Cebolla deposits on Cebolla Creek in the same county consist of an immense ledge of titaniferous ore, yielding from 9 to 36 per cent of the objectionable titanic acid. The deposit appears, though of enormous size, to be valueless.

On Powderhorn hill are three veins of manganese, each about two feet wide. The ore is a black oxide, yielding metallic manganese 52.20 per cent. Four miles from this is a deposit of brown hematite or limonite. The vein is six feet wide. It appears to be a bedded deposit and low grade metallic iron, not being more than 33.86 per cent.

On Taylor River, twenty-seven miles north of Gunnison City, is a large deposit of manganiferous iron ore of a bedded character, its width is not yet determined, but at least 12 feet have been so far exposed. It is a calcareous vein ore, almost a ferruginous limestone. Analysis:

Silica	0.82
Protoxide of Manganese	13.92
Peroxide iron	39.01
Lime	19.55
Magnesia	6.03
Carbonic acid	21.05
	100.38

The carbonic acid of this ore would be expelled by roasting or by treating it in a kiln like a common limestone. The final product would then be:

Metallic manganese	13.65	per cent.
Metallic iron	33.57	"

The value of this bed lies in the fact that the lime and magnesia are incorporated already in the composition of the mass so that no flux need be added. Spiegel is made in parts of Europe by crushing iron ore, manganese ore and limestone mixing, pressing into rough bricks, and charging in that form.

This deposit is within thirteen miles of the D. & R. G. Railway. As regards faculities for establishing oven works in connection with these Gunnison iron deposits, fuel and lime, the other *desiderata* besides iron are in abundance in the county and of the highest class. The coal of this region produces the best coke in the West. For example: that at Crested Butte yields coke with 90 per cent. fixed carbon, volatile matter 0.42 per cent., ash 8 per cent. and no water, whilst there is anthracite running 89 per cent. in fixed carbon and non-coking coal 55 per cent. with ash only 4 per cent.

MINERAL STAINS.

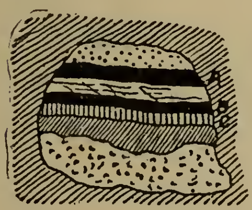
Ores are sometimes disseminated through sedimentary rocks in which they have been chemically deposited.

Some of our Triassic red sandstones in South Park are locally stained green with carbonate of copper. The sandstones contain impressions of fossil leaves beautifully colored with this material, but no profitable deposits of copper have been found. Copper stains also impregnate the hornblendic gneiss near Golden, and on a line or belt at various points along the eastern flanks of the mountains. Occasionally flakes of native copper are found, but prospecting has developed no profitable deposits of copper ore.

Such blue and green stains of carbonate of copper frequently lead to the discovery of a true vein, containing copper or iron pyrites at depth, from which the carbonate stains have been derived by surface action. Such stains are common in every mining district, associated with the surface indications or "float" of important veins or ore deposits.

ORE BEDS IN COLORADO.

"Ore beds are metalliferous deposits interstratified between sedimentary rocks of all geological ages." "They lie parallel to the planes of stratification and follow all the contortions of the enclosing strata, hence they are thrown into folds, troughs, arches, saddles, or basins. The upper portions of the arches may often have been removed by erosion, or the strata may be faulted."



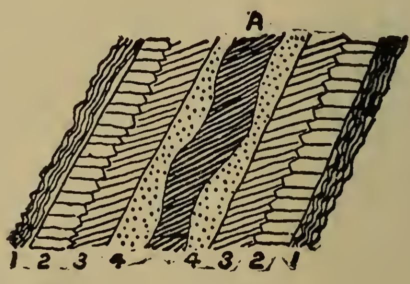
ORE BEDS.

The ore deposits or beds at Aspen occupy a faulted synclinal fold or basin. The enclosing rock is limestone, in part dolomitic. At Leadville the deposits occupy part of a series of faulted anticlinal arches and synclinal troughs, of which the Mosquito range is the main axis. The beds lie between dolomitic limestone and sheets of porphyry. The ore beds partake of all the folding, faulting and other contortions which the enclosing rocks have suffered in the upheaval of the mountains.

The thickness of such deposits varies much and may gradually thin out and disappear, but may also continue long enough for all mining purposes.

Often there are no sharp limits between an ore bed and the enclosing rocks, or between the ore bed and the walls, if walls exist at all. The ore appears to impregnate the surrounding rock by a chemical interchange between the elements of the rock and the ore. Such a "metasomatic" interchange, "substitution," or "replacement" appears to have taken place in the argentiferous lead deposits of Leadville and Aspen between the ore and the limestones.

According to Phillips, "a true ore bed never produces a 'combed' or '*ribbon*' *structure* made up of symmetrical layers such as is common in so-called 'true fissure veins,' and is usually without the crystalline texture observable in veinstones."



RIBBON STRUCTURE OF VEIN.

FAULTS.

Ore beds are subject to faulting, as at Leadville and Aspen. The common rule is that the footwall of the fault fissure usually rises or remains constant whilst the hanging wall falls down. When the opposite to this occurs it is called a "reversed fault."

The ends of the strata containing the bedded ore deposits on the footwall side of the fault fissure are commonly found bent downwards towards the fault as if dragged down by the fallen hanging wall side. In this case the ore deposit may be looked for below. The reverse, however, sometimes occurs. See No. 14, plate No. IV.

A faulted region is one in which great folding or crumpling, due to horizontal, lateral or tangential pressure, has taken place, and where the folding has reached its utmost tension, the fold has broken, and a slip or fault is the result. See plate No. IV, figures 1 and 17.

Thus in the South Park region adjacent to Leadville we find the horizontal strata of the Park as it approaches the Mosquito range becoming gently folded, the folds increasing in closeness and steepness the nearer they come to the range, until as we pass up Four-Mile canon, which gives a complete cross-section of the Mosquito range, we find the axis of the range to be formed by a magnificent and very steep arch, breaking down abruptly into the great London fault, which runs along and splits the axis of the range for twenty miles. Still further on in the direction of Leadville we pass over a series of parallel faults, each one representing a steep fold that once preceded the faulting. Faults have their points of greatest depth, and die out at either end, often in folds, this being well illustrated at Leadville. Great faults are accompanied by minor parallel faults, and also by cross faults intersecting them diagonally. Figure 4, plate IV.

INDICATIONS OF FAULTING.

The surface indications of a fault are sometimes a "sag" or sudden depression in the outline of a hill. Thus from the Mosquito range we descend to Leadville by a series of steps or benches, each marked by a sag on the hill slope, the depression often constituting a little ravine filled by a water course and abundant vegetation.

In a mine such movements are indicated by slickensided or polished surfaces of the walls, or by a general broken up character of one wall or the other, due to the grinding of the walls in process of slipping. This grinding, as in the case of the great Comstock mine, sometimes reduces quartz to a powder, like "commercial salt." The polished slickened sides often show groovings or striæ, indicating the direction of the slipping motion; such motion was probably slow or by short jerks, and may sometimes have been accompanied by earthquakes.

In a good section of a cliff, such as is sometimes afforded by a deep canon, by observing some well defined or peculiar stratum high up the face of the cliff, we may notice its position out of place further down and easily compute the amount of slip, but when slips or faults amount to thousands of feet of displacement it is only by an accurate knowledge of the original geological position of the displaced member that we can form an estimate of the amount of slip. For example, if the strata of a period such as the Silurian, whose geological position is near the base of the series, should abut against rocks of the Tertiary, whose position is near the top, we should conclude that a slip of many thousands of feet had occurred. We should know that the Silurian had risen many thousands of feet and that the Tertiary had fallen correspondingly, so as to bring these two widely distant periods on the same level. By observing somewhere else the thickness of the strata composing the periods intervening be-

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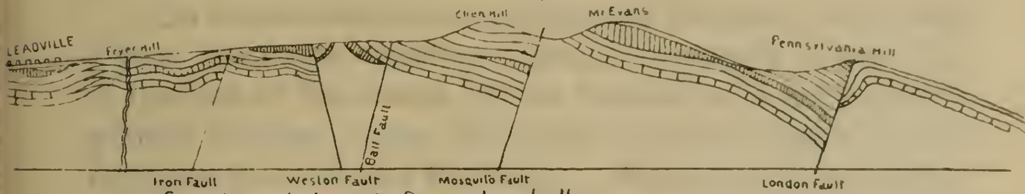
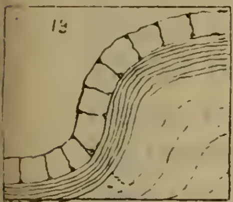
Folded and Faulted Plateau Region (Powell)

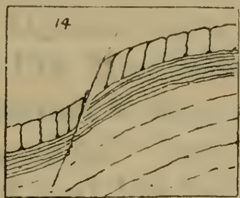
17



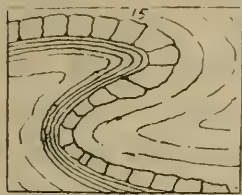
Structure of Mosquito Range Leadville



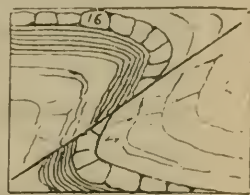
Fold



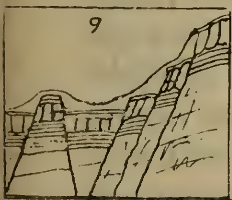
Fold Faulting



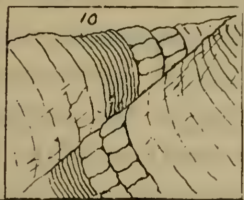
Reversed Fold



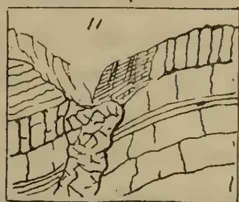
Reversed Fault



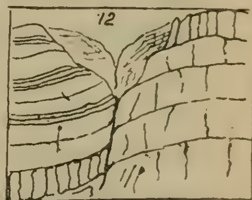
Complete Normal Faults



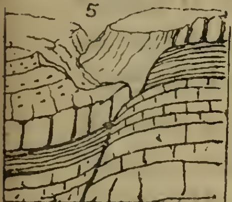
do. Reversed Fault



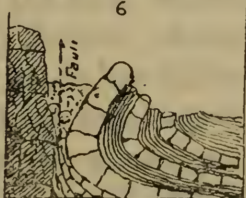
Walls Wide Apart



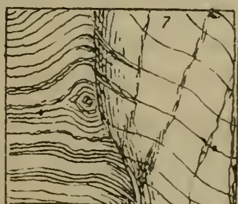
Walls Close Together



Beds Bent by Fault



Beds Overthrown by Fault



Contortion by Fault

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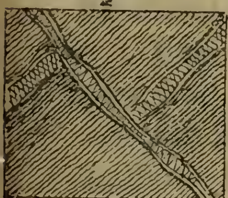
Dyke in Fault Fissure

2



Vein Faulted by a Vein

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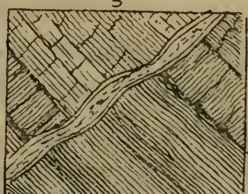

Vein in a Fault Fissure

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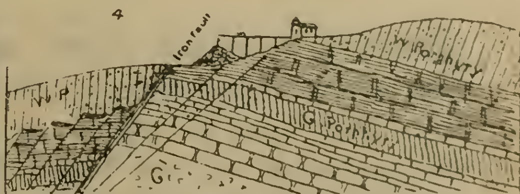
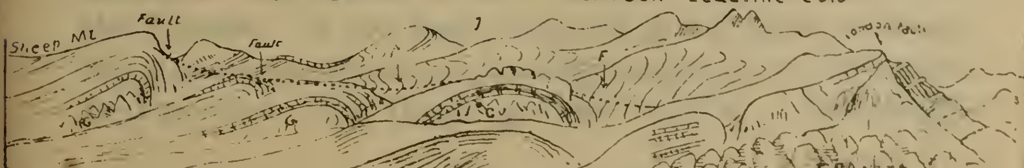


Iron Fault Leadville Colo



Folds and Faults in the Mosquito Range, South Park Colorado

FOLDS AND FAULTS

PLATE IV.

tween the Silurian and the Tertiary, we should form an estimate of the amount of slip.

On Castle Creek, near Aspen, the Mesozoic red strata, whose thickness numbers several thousands of feet, lies in the bed of the creek at the bottom of a lofty cliff of granite forming Aspen Mountain, upon the top of which rests the Silurian and Paleozoic. A great fault has therefore occurred by which the Paleozoic series has been lifted up and the Mesozoic series fallen down. The great fault fold of the Elk Mountains on Rock Creek in the same region, is another striking example of how intense folding passes gradually into profound faulting. The downward direction of the fault fissure is commonly slanting rather than vertical, it is not always regular, either; having sometimes a steeper dip in one place than another, while its horizontal direction across the country is not always straight, but zigzag or curved. In a faulted district like Leadville there is generally a prevailing direction of up-throw or down-throw, thus at Leadville the up-throw is to the east which is also generally the footwall of the fault fissure, whilst the hanging wall or western face of the crack has fallen. The greatest amount of slip in that district amounts to some thousands of feet, and that is near the center of the district, the slip diminishing north and south and dying out in folds represented by rounded hills.

The exact line of the fault fissure is generally obscured on the surface by crushed rock, *debris* and vegetation. In the mines, at depth we may find both walls wedged tightly together, and one side or both much crushed. Sometimes a little mineral may be found on the "cheeks" of the fault, dragged down from ore-bearing strata from above, or possibly leached from them and re-deposited. See figure 4, Plate No. IV. The fissure of the Iron fault in the McKeon shaft is 3 feet wide in places, filled with broken rock and a dark clay. The cheeks are altered by surface waters impregnated with iron oxide, and what ore there is is water-worn. The fault plane has been exposed for several hundreds of feet by the McKeon shaft. The outcrop of the fault on the surface is irregular, its direction downwards, is steep, but accompanied at intervals by benches with rich deposits of ore on them. The main fault is accompanied by a series of smaller faults adjacent to it. From the movement of timbers, by 5° or over, in some of the mines adjacent to the fault plane it is suspected that the fault movement is still continuing. The same suspicious facts have been observed in the Centennial mine at Georgetown. Nor is this improbable, since we have evidence of comparatively recent elevation of the mountains in various parts of the Rocky Mountain system.

UNSTRATIFIED DEPOSITS, FISSURE VEINS, ETC.

Mineral veins are changeable in character, and their appearances of a perplexing and complicated nature. There is gradual passage from one form to another, so that it is difficult to classify them. There is often no such sharp distinction between one form of ore deposit and another as legal disputes would sometimes demand, and a witness should hardly be called upon to assert on oath that such a vein is a "true fissure," or another a "bedded vein," or a third a "segregated vein." "Nature abhors straight lines" and sharp distinctions, and delights in blending one form imperceptibly with another.

Phillips divides veins into two classes, "regular and irregular veins." "Regular unstratified deposits include true veins, segregated veins, and gash veins." "Irregular deposits include impregnations, fahlbands, contact and chamber deposits."

Veins are collections of mineral matter, often closely related to but differing more or less in character from the enclosing country rock, usually in fissures formed in those rocks after the rocks had more or less consolidated.

All veins do not carry metals; some are merely barren quartz, feldspar, or calcspar, like the barren veins we so often see traversing granite or limestone rocks.

Veins may divide, "split up," or thin out, and are irregular in shape and structure, owing to the irregular width of the fissures and to other causes.

DEFINITION OF MINING TERMS.

The rock in which a vein is found is called the "country rock," *e. g.*, limestone, granite, porphyry,

The portions of country rock in direct contact with the vein are called respectively the "hanging wall," or roof, and the "foot wall," or floor. This is only in inclined or flat veins, as a vertical fissure vein can have neither roof nor floor, but only two walls, east and west, north and south, according to the compass. The inclination of a vein to the horizon is its "dip." The horizontal direction of a vein at right angles to its dip is its "strike." The latter may commonly be observed along the surface outcrop, the former either in the workings of the mine or where the vein is exposed on the side of a canon.

Both dip and strike of a vein often vary much, the former with depth, the latter with extension across the country. A vein or ore deposit will not unfrequently begin with a gentle dip, and increase rapidly in steepness with depth. The ore deposits on Aspen Mountain commonly begin with a dip of 25°, and at a depth of less than a thousand feet reach 60° or more.

As fissure veins commonly occupy fault fissures, their irregularities in dip and strike correspond to those we have already spoken about, under faults.

The angle of dip is usually taken from its variation from a horizontal, not from a perpendicular line. Thus a dip of 75° means one that is very steep, while one of 10° is a gentle inclination.

A layer or sheet of clay called "gouge" or selvage often lines one or both walls of a vein between the country rock and the gangue or vein proper. It is derived from the elements of the adjacent country rock decomposed by water, and sometimes by the friction of the walls of the fissure against one another, or against the vein matter, in the process of slipping and faulting, which is often shown by its being smoothed, "slickensided," polished or grooved. Gouge often contains some rich decomposed mineral in it, such as sulphurets of silver. It sometimes occurs in the heart of a vein, especially if that vein has been re-opened anew by movements of the strata. The "Chinese tallow" gouge of Leadville results from the decomposition of the feldspars in the adjacent white porphyry and is a hydrous silicate of alumina.

In the granite veins in Clear Creek County the gouge is derived from the feldspars of the granite. Gouge is sometimes useful in defining the limit of the vein between walls, thus preventing unprofitable exploration into the "country." It is also a guide for following down a vein when mineral and gangue may be wanting or obscure.

Both walls are not always clearly defined by slickensided surfaces, by gouge or other mark, and so at times the vein is lost.

False walls, caused by movements in the adjacent strata, by joints, etc., also mislead.

It is not uncommon in Colorado for a fissure vein to have but one clearly defined wall, the other, if it exists, being obscured or changed by mineral solutions. Sometimes two cracks or fissures occur parallel to each other and the intervening country rock has been altered and mineralized into a vein. It is probably in this way that many wide veins were formed.

Mr. Emmons has found that fissures are formed by great movements of the earth's crust or by local contraction of the rocks. That a fissure is not necessarily one with well defined walls, at considerable distances apart, filled after the formation of the fissure, but that the ordinary cracks or joints in granite quarries extending regularly to great lengths or depths illustrate the original fissures which have been changed by percolating waters carrying mineral solutions, into veins and deposits of ore. In all crystalline and sedimentary rocks these cracks or joints run parallel to each other at various distances apart, often plentiful and close together. In cases where percolating waters were charged with the proper metals and veinstone matter and the necessary chemical and physical conditions existed, the rocks lying between those cracks or joints were altered into ore.

As one element was dissolved another took its place, so according to this authority it would seem that even a fissure vein may be only a sort of "metasomatic replacement" of rock by mineral. Hence what is commonly accepted as a "wall" of a vein is not necessarily one, and cross-cutting, in order to determine the lateral boundaries of the ore, is safer than to rely on supposed walls. A so called "slip" has often been followed by a miner as a supposed wall, until by accident he broke through and found good ore on the other side. If veins are formed according to Mr. Emmon's theory, the occasional loss of one or both walls is easily accounted for.

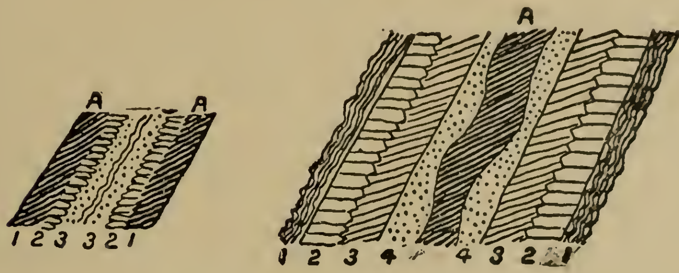
Cross veins of a more recent age sometimes cut or fault an older vein. The point of intersection is generally rich in mineral. Cross veins must not be confounded with "leaders," which are the filling of minor cracks extending off from the vein, and are sometimes sufficiently profitable to work. While they sometimes lead a prospector to the main vein, they may also lead a miner under ground astray from the true vein.

The splitting of a vein by a "horse" or large fragment of the country lying in the vein may be mistaken for a true cross vein, or the original fracture of the fissure may have been in the form of a star or like the spokes of a wheel radiating to the hub. In such cases there are no true cross veins. But when, as in the San Juan district, we have two well defined sets of veins, one striking north-east by south-west, and the other north-west by south-east, they cut each other diagonally, the cut vein being the older. These opposite sets of veins have been formed at different times. Many contain a characteristically different class or variety of minerals. Thus in Cornwall, England, one set carries tin and the other lead.

SIGNS OF A TRUE FISSURE VEIN.

True fissure veins show signs of motion or slipping on the sides of the fissure, such as slickensides, gouge, crushed walls, "horses," or "breccia," the latter being small portions of the country rock fallen into the vein and cemented by vein matter. In the Comstock, the quartz is ground to powder. The vein itself, though occupying a healed fault fissure, may be itself faulted by later movements in the mountain after the vein was formed. Some of the fissure veins on Engineer Mountain, San Juan, are so dislocated.

The vein-filled fissures being a line of weakness, may be re-opened by mountain movements, and other or



RIBBON STRUCTURE OF VEIN.

different combinations of ore introduced into the heart of the vein. Such a re-opening would be marked by a succession of "combs" or banded ribbon-like deposits of ore, and by gouge matter.

OUTCROP OF VEINS.

The outcrop of a vein is that which appears at the surface and usually attracts prospectors to the spot. Sometimes it may be, as in the San Juan district, a bold vein of hard, white or rusty quartz, standing up in relief, by its superior hardness, above the surrounding country, like a low wall. Or again, in the same district, from being composed of softer or more soluble substances than the prevailing eruptive lava sheets, instead of a wall it causes a depression or trough on the side of a hill forming the pathway for a rivulet and marked by luxuriant vegetation. Commonly the outcrop consists of a decomposed mass of rock stained with oxide of iron and streaked here and there with green or blue carbonate of copper, and is called "float" or "blossom" by the miners. This "float" is the chemically

FISSURE VEINS.

changed or oxidized portion of the true and unchanged vein lying deeper below the soil.

In this "blossom rock" free gold is not unfrequently found, but unaltered sulphides, such as galena or iron pyrites, are rarely met with on the outcrop. In the San Juan district, on Mineral Point, we have, however, found galena at the grass roots, and broken off large chunks of it from a quartz vein outcropping on the surface.

In gold-bearing veins such an oxidized condition is desirable if it continue down to any depth, for so far as it continues the gold is free, and the ore is a free milling one, easily treated, and often exceedingly rich in gold, as in the celebrated Bowen mine of Del Norte; but as soon as the hard white quartz and the unoxidized pyrites of the true vein is reached, the ore is no longer free milling, but must be smelted. The gold may still be found free, perhaps, in the hard quartz, but if the pyrites should not prove rich in gold, the palmy days of the mine may be considered as past. Many such rich deposits on the surface, abounding with specimens of free gold, have proved great disappointments with depth.

WIDTH OF VEINS.

Veins may vary in width or thickness from half an inch to a hundred feet. They also pinch or widen at intervals in their downward course. The widest "mother" veins are not always the most productive, though they are very persistent in length, and we may suppose in depth also. In the San Juan district the "mammoth" veins of quartz, often a hundred feet wide, are not the favorites for development, the ore being found too much scattered in them, and the development less easy than in those ten, twenty or thirty feet wide, where the metal is more concentrated. These mammoth veins in the San

Juan are easily traceable for miles over the surface of the country and down the sides of the deep cañons. Their limiting depth has never been reached, and probably never will be by mining.

DEFINITION OF TRUE FISSURE VEINS.

True fissure veins are popularly defined as filling fissures of indefinite length and depth, commonly occurring in parallel systems, traversing the surrounding rocks independently of their structure or stratification, and commonly, though not necessarily, at an angle different from that of the stratification—in other words, cutting across the planes of stratification. These veins originated in fissures, not necessarily wide open ones, but on the contrary, rather narrow cracks, descending, however, to great depth such as those produced by faulting, or the general cleavage lines of the mountain. The latter may be frequently observed in every cañon, and also in the sedimentary rocks of the foothills and even along the flat surfaces of the plains. They are very conspicuous in the plains around Trinidad, and are there not unfrequently occupied by a series of narrow parallel dykes of basalt instead of by mineral veins. Cleavage lines or joints are familiar to every stone-quarry man.

These cracks are caused by extensive movements of the earth's crust in the process of mountain uplift, and also on a smaller scale by contraction of the rocks in cooling from a heated or molten condition, or even in consolidating from a soft or muddy condition.

The two walls enclosing a vein do not generally coincide, as might be expected, since the vein occupies a line of fault. A true fissure vein may in some part of its course coincide with the dip of the surrounding strata. As the plane of stratification or line of division between one stratum and another is a natural line of weakness, a crack once started would be liable to follow it for some distance. And when uplift occurs such places are liable to slip one upon the other and a true parting fissure ensue, conformable to the prevailing dip. Such a vein might appear at first to belong to the class of so-called "bedded veins," but if with depth it should be discovered to be cutting across the strata it would be pronounced a true fissure vein. The appearance of slickensides or other signs of motion on the walls of the apparently "bedded portion" would then prove it to belong to the "true fissure" class and that actual fissuring had taken place prior to the vein-filling.

CAUSE OF POCKETS IN FISSURE VEINS.

As a fault fissure in its downward course usually pursues a zigzag rather than a straight course with smooth surfaces on either side of the crack, the inequalities of one face of the crack are brought into opposition to the inequalities on the other face as one or the other side of the fault slips up or down, and thus are produced pinches and wide cavities, which give rise to the "pinches" and "bonanza," "pockets" so common in fissure veins.

A so-called true fissure vein may sometimes have advantages over some other forms of vein occurrence, from its persistency and comparative regularity to great depths. It must not, however, be expected that it will continue equally rich or equally poor throughout its course. There may be comparatively barren spots and rich spots, pinches and widenings, local combinations of richer or poorer varieties of mineral. But the vein as a rule is not likely to entirely give out.

RICHNESS WITH DEPTH.

There is no scientific reason why a vein should "grow in richness and size with depth." This is a popular fallacy, originating from the now less accepted theory that veins were formed by the precipitation of precious metals by heated rising waters or vapors, and hence that the greater concentration would take place at greater depths. The "lateral secretion" theory now commonly accepted ascribes the deposition of ore to solvent waters reaching the vein from ground quite near to it and coming naturally from above and the sides quite as often as it is ejected upward by pressure from below.

In Idaho Territory, says Mr. A. Williams, "the rule is rather that veins grow less rich and strong with depth, though strong veins may continue metalliferous to a greater depth than mining can ever reach."

"The thickness of the earth's crust which we are able to explore is very limited. Increase of heat, as in the deep Comstock mine, and other natural difficulties, limit us to a few thousand feet—3,000 at most. These deep mines have not, as a rule, proved richer with depth, but to the contrary. Some veins have been worked through alternate zones of richness and barrenness. The Comstock, which has been opened for four miles in length, and to a depth of 3,000 feet, shows the ore bodies to be scattered irregularly and the barrenest ground is at the bottom. On the other hand some of the most celebrated mines derived their wealth from rich ores encountered near the surface and have proved most disappointing with depth."

Atmospheric action for a long period has often reduced the ore to its richest compound, and when the hard material is reached, leanness sets in. This, as we have observed, is commonly the case with gold veins. The richness of the Leadville mines is derived from their decomposed compounds. Again, as the surface crust can be so little explored by mining, it is to be remembered that the erosion by glaciers and waters has already removed thousands of feet of the vein, so that we are able to examine only a small fraction of it while an unknown quantity lies in the depths below. If these veins, then, continue to the supposed great depths below, we are very far from their starting point, and erosion having removed their upper portions, we cannot find their surface finishing point; in other words, it is not a fresh "ready made" vein we find, but portions of an old vein already extensively mined by the process of nature.

So far as our experience goes in Colorado, after a moderate depth is reached below surface action, or below the "water level," a fissure vein may grow richer or poorer, wider or narrower with depth, without any law except local experience in a district.

VEINS IN GROUPS.

Fissure veins occur in clusters and nearly parallel groups, forming a mining district, and again in that district certain peculiar veins may be grouped together, forming a "belt." Thus Boulder district occupies a certain isolated area, outside of which few mineral deposits occur for a long distance. We have also in that district several distinct belts carrying different characteristic ores, such as the telluride belt, marked by rare telluride deposits, the pyritiferous gold-bearing belt, and the argentiferous galena belt. The Central City region is characterized by auriferous pyrites belts, Georgetown district not far distant, by argentiferous belts, and Idaho Springs, lying between the two, by both gold and silver belts.

RELATION OF VEINS TO ERUPTIVE FORCES.

The ultimate cause of the richness in veins of a district or locality is, that local dynamic and eruptive forces were more energetic there than elsewhere, causing great disturbance of the rocks accompanied by fissures, and eruptions of porphyry.

Thus at Leadville the Mosquito range is violently folded and fractured, eruptive rocks have issued abundantly, and associated with such phenomena we find great lead and silver deposits.

Further south the great San Juan district is split up in an extraordinary manner with great fissure veins. The region is an eruptive one, consisting of prodigious flows of eruptive rocks traversed, not unfrequently, by newer eruptive dykes.

In the Gunnison district the strata have been overturned, disturbed, folded and faulted in an extraordinary manner by the intrusion of great masses of eruptive rock forming the peaks of the Elk Mountains. The strata every where are riddled by dykes or intrusive sheets, and the evidence of heat is apparent in the general metamorphism of the entire region. Mineral veins abound. The same phenomena are repeated more or less in the neighboring region around Aspen, at Pitkin, and at Tincup.

At Boulder, Central and Georgetown there is a concentration of eruptive dykes locally in each district and few dykes or eruptive rocks outside of those districts. On the other hand we have no ore deposits in the undisturbed rocks of the plains or the flat basins of our parks, and notably our mining districts are for the most part well in to the core of the mountains, where in the nature of things, folding, crumpling, faulting, eruptions and metamorphic heat were more energetic than along the flanks and foothills of the range which have usually proved unproductive.

The older eruptive rocks such as the quartz-porphyries and diorites of the Leadville, South Park and Gunnison districts, are more favorable to the production of ore deposits as a rule, than the more modernly erupted lavas, such as basalt or dolerite which we commonly find occurring in dykes and surface overflows traversing or capping our Cretaceous and Tertiary coal fields along the foothills as at the Table Mountains at Golden and Trinidad.

Some of the lighter colored and somewhat recent lavas like the tufaceous rhyolite, which caps so many of the Tertiary mesas on the Divide between Denver and Colorado Springs, have also hitherto proved barren, whilst the rhyolites and andesites of the San Juan, Cripple Creek and Silver Cliff have produced a great deal of ore. The older eruptive rocks, as we have stated, are nearly all of an intrusive character, never having reached the surface, while the newer ones bear evidence of having flowed over the country like modern lava streams, as is shown by spongy scoria on their surface, and may be called "extrusive."

In Colorado the ore body is not usually found in the heart of an eruptive sheet or dyke of porphyry, so much as at the line of its contact with some other rock, such as limestone, granite or gneiss. Notable exceptions occur to this as throughout the San Juan, Creede, Cripple and Silver Cliff districts.

CONTACT DEPOSITS.

The "contact" ore deposits of Leadville occur at the contact of quartz, porphyry and dolomitic blue limestone.

Some of the veins at Boulder, Central and Georgetown are at the contact of porphyry and granite or gneiss.

Exceptions occur, however, where mineral is found either in the heart of a dyke, or the whole dyke may be so impregnated as to constitute in a sense a vein. These exceptions are generally confined to pyritiferous gold deposits.

GOLD–BEARING DYKES.

Suppose a dyke or mass of eruptive rock to be thoroughly impregnated with gold-bearing pyrites. Near the surface and often for a considerable depth the rock is decomposed and the pyrites oxidized into rusty iron ore, liberating the gold which is entangled in the "gossan" in wires, flakes or even small nuggets. As long as this decomposed or oxidized state continues, the ore is free milling, but with depth the dyke is found in its primitive hardness, studded with iron pyrites which may or may not prove rich enough for the more expensive treatment of smelting or chlorination. Such gold-bearing dykes are found at Breckenridge, South Park, also in Idaho Territory and in old Mexico, and many other gold-bearing regions.

The Printer Boy gold mine at Leadville is a vertical deposit in a jointing or fracture plane in a dyke of quartz-porphyry, rusty and much decomposed near the surface, where it yielded free gold; with depth this passes into copper and iron pyrites. The vein is from an inch to four feet in width, stringers carrying ore extend into the porphyry, which is highly charged with pyrites which doubtless supplied the vein with mineral through the agency of surface waters. In Arizona, near Prescott, at the Lion mine we find a green dyke of eruptive diorite penetrating granite. This dyke is traversed by numerous small veins of white quartz which near the decomposed and rusty surface are rich in free gold. At a slight depth the quartz veins become charged with unoxidized iron pyrites sufficiently rich in gold to merit treatment by smelting. The surface ore is treated by a simple "arrastre," and is, of course, free milling. The gold seems to be mostly confined to the quartz veins. At the Antioch mine at Leadville free gold of low grade is disseminated through 100 feet thickness of a huge mass of quartz porphyry and the mine is worked as a great open quarry. At Cripple Creek gold impregnates andesite and rhyolite lavas along certain lines and also is found in quartz veins.

FISSURE VEINS IN IGNEOUS AND GRANITE ROCKS.

The San Juan district is an exceptional case where immense numbers of fissure veins penetrate igneous eruptive sheets. The fissure veins consist of hard gray jaspery quartz, traversing lava sheets whose united thickness is from 2,000 to 3,000 feet. The veins produce lead, bismuthinite, gray copper and other silver-bearing ores. At Creede, silver deposits occur in veins in andesite and rhyolite lavas.

In Colorado true fissure veins are most characteristic of the Archæan granitic series. In fact, all the veins in that series are fissure veins. Locally they occur as in the San Juan, cutting through eruptive rocks. Outside of these formations few true fissure veins occur.

An exception may be made of the Gunnison and Elk Mountain region where the fissures traverse all the formations from Archæan granite to the top of the Cretaceous coal beds. Nearly all other mineral occurrences, such as those in the limestone regions, come under the class of bedded-veins or blanket-veins, pipe-veins or "pockets" and show none of the characteristics of slipping motion or fissure action. Under this latter class the Leadville and Aspen deposits may be grouped.

Ore deposits commonly occur at the junction or contact of two dissimilar rocks, as between quartzite and limestone or limestone and dolomite, or between porphyry and some other rock.

Lodes occur also between the stratification planes of the same class of rock, sandwiched in between two layers of limestone, and sometimes impregnating the layers on either side for some distance from the dividing line between the two stratas, which is commonly the line of principal concentration of ore, and often descend from this concentration line, through the medium of cross joints, to form large pockets in the mass of the limestone. The Aspen and Leadville deposits are of this character. Also when ore bodies occupy a true fissure, *i. e.*, one cutting across the stratification planes, they may locally, for a short distance, impregnate the adjacent walls or country rock more or less. Our fissure veins in granite and gneiss often impregnate the walls to a small extent.

Mineral deposits favor as a rule the older rocks, such as the Archæan and Paleozoic series, probably because heat and metamorphic action are commoner in these older rocks, which have felt all the throes of the earth from past to present times, than in the more recent ones, and such circumstances, as we have stated, are peculiarly favorable to vein formation and mineral deposition.

The bulk of our precious minerals in Colorado come from the older Archæan and Paleozoic series of rocks, the exception being the Gunnison region around Crested Butte, Irwin and Ruby, where ore comes from fissure veins in the Mesozoic-Cretaceous rocks. The exception is accounted for by the local metamorphism, heat and eruptive phenomena of that region.

The veins in the San Juan have also been ascribed by some to the Tertiary period, owing to their occurrence in certain supposed Tertiary lavas covering that district. The same applies to Cripple Creek and Silver Cliff districts.

Besides heat, metamorphism, dynamical disturbances and eruptive agencies, other minor circumstances may favor ore deposition. Certain rocks, such as limestones, may offer, by their tendency to solubility and chemical reactions, more favorable conditions than others for mineral solutions to deposit by "metasomatic" interchange between mineral and limestone, until the limestone is gradually replaced by ore, much in the same way as the elements of a water-logged trunk of a tree are replaced by silica in the process of fossilization.

DESCRIPTION OF ERUPTIVE ROCKS.

As eruptive igneous rocks commonly called "porphyries" play so important a part in connection with ore deposits, it will be well to give such a general description of them as will enable a miner to recognize and distinguish them in the field. See plates Nos. VII and VIII.

They differ from ordinary sedimentary rocks, such as sandstones and limestones, in their origin, mode of occurrence, structure and appearance.

Their origin is that of fire, not of water. They have been thoroughly fused and melted in the bowels of the earth. They occur erupted through fissures, piercing both the foundation granite and overlying quartzites, limestones or sandstones, prying open the leaves of the sedimentary strata, and forcing their way in between the

PLATE V.

strata in horizontal sheets, arching up the strata and faulting them and filling the space they have opened with a thick, dome-like, lenticular mass of porphyry sometimes 1,000 feet thick, called by geologists a Laccolite, which ultimately thins out either way in a sheet, terminating in a wedge between the strata, showing their eruptive intrusive character and their igneous origin. The internal structure of these rocks is thoroughly crystalline, as distinct from those of sedimentary aqueous origin. The latter show either to the naked eye or under the microscope that they are made up of more or less water-worn fragments of other rocks.

The eruptive rocks are of course unfossilliferous by reason of their igneous origin. They are, as a rule, harder than most of the sedimentary rocks and will not generally split up into lamina like shale, slates, or some sandstones. There is no "way of the grain" to them as there is in those of aqueous origin. They break like cast iron or other crystalline substances, and both on the surface and fracture show their distinctly crystalline character.

CHARACTERISTICS OF PORPHYRIES.

The component minerals of these intrusive porphyries are principally quartz and feldspar, together with mica, hornblende or augite.

In color, these rocks are commonly some shade of gray or green, maroon, or even white, but their most striking characteristic is a general spotted appearance. This arises from large perfect crystals of quartz or feldspar being set in a finer-grained crystalline paste or background, and standing out prominently from it. This base or background may be comparatively coarsely crystalline, finely crystalline, or so finely crystalline that the crystals may only be discovered by the microscope, and the larger crystals of feldspar seem set in the paste, like plums in a pudding. In the depths of a mine the porphyry is commonly much decomposed, and even passes into "gouge" or clay matter. Its spotty character, from the presence of individual feldspar crystals, even then may identify it at times, or the aluminous character of the decomposed rock may be sufficient.

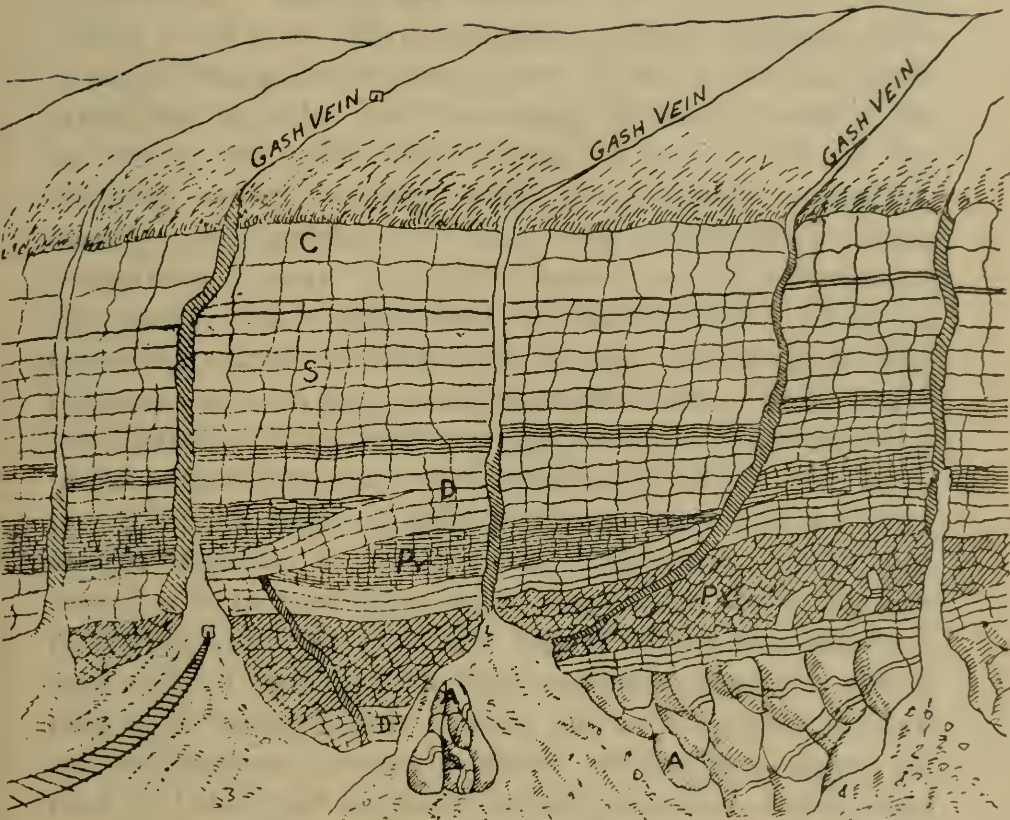
When feldspar is the main constituent it is called a felsite-porphyry. When a certain amount of quartz is observable, a quartz-porphyry.

Diorite also belongs to this intrusive eruptive class, differing mainly in the fact that its feldspar is plagioclase instead of orthoclase. Hornblende is generally a prominent constituent, and gives it commonly a more or less dark gray or greenish hue. In appearance it is not unlike common granite or syenite, but its eruptive occurrence distinguishes it at once from them.

The main peaks and dome-like masses of the Elk Mountains are principally diorite, which in old reports used to be called "eruptive granite." It is generally finer than the common quartz porphyries. From the dark olive green that it assumes when weathered it has been called "greenstone."

MODE OF OCCURRENCE OF QUARTZ PORPHYRIES IN SOUTH PARK.

Quartz porphyries are among the commonest varieties of intrusive eruptive rocks in the mining districts of Colorado. The eruptive rocks of the Leadville and South Park districts are principally quartz porphyries. In almost any cañon in the Mosquito range between South Park and Leadville we get a section of a thousand feet or more of different rocks, and see the cañon cliffs



INTRUSIVE PORPHYRITES, BUCKSKIN CANON

Py. PORPHYRITES D. CAMBRIAN QUARTZITE, S. SILURIAN LIME C. CARBONIFEROUS. A. GRANITE. —Appearance of Intrusive Sheets as seen from the Canon below.

PLATE VI.

to be composed at the base of granite and gneiss, upon which rests, at a slight angle, a great thickness of sedimentary beds. These are principally quartzites and limestones. Passing up through the granite, we may notice a dyke of quartz porphyry, which perhaps when it enters the sedimentaries, opens them up between their strata and intrudes itself in a mass, gradually running out at either end. The dark green or gray color of the eruptive rock, together with its columnar structure, readily distinguishes it from the sedimentary beds. Sometimes a great "laccolitic" mass is so formed between the strata, which are arched up and faulted. At other times the eruptive sheets look almost like interstratified rocks, so well do they conform to the strata. Their intrusive character, however, is very apparent by their tendency to cut across from one set of strata to another. The feeding dyke or vent of this porphyry may not be seen always attached to its laccolite, sheet or branches, but may be found perhaps miles away as a dyke coming up through granite, from the top of which the sedimentary rocks, together with their included intrusive sheet, may have been entirely eroded off, and we have to look for the porphyry sheet elsewhere. Sometimes, again, we may find the great laccolite entirely denuded of the strata which once arched over it, and it may constitute, as in the case of the principal peaks in the Elk Mountains, a prominent peak or dome of eruptive rock. Crested Butte Mountain, Gothic Mountain, both of quartz porphyry, and White-rock and Snow-mass Mountains, of diorite, belong to this laccolitic type—also the Spanish Peaks, reservoirs of congealed eruptive rock, revealed by the denudation of thousands of feet of sedimentary rock, that in some cases once arched over and lay above them. Whenever these porphyries or diorites are found in Colorado their presence implies that great denudation has occurred, uncovering these deep-seated subterranean reservoirs of molten rock, for, as we said, they are all intrusive sheets. None of them ever flowed out over the surface, but they came up from depths unknown, and not having eruptive energy enough to penetrate to the surface of the earth, they spread out and congealed beneath that surface, forcing their way into any local weakness among the adjacent strata. See plate.

A dyke not unfrequently is the cause of the existence of a prominent peak. Thus Mount Lincoln, over 14,000 feet above the sea, owes its prominent character to a dyke of quartz-porphyry which has come up through the granite and sent out intrusive sheets between the overlying quartzites and limestones binding the mountain mass together as by a tree with locking branches, and so preserving it from the general erosion as a noble monument of fire and water. These eruptions appear to have occurred at different times, as we frequsntly meet older intrusive sheets cut by dykes and intrusive sheets of a newer and a different variety of porphyry. The eruptions in the South Park region seem to have occurred till near the close of the Mesozoic epoch, as these dykes and sheets are found in rocks of that epoch as well as penetrating the older Archæan and Paleozoic series.

The eruptive rocks we have mentioned are those most commonly associated with our ore deposits, but there is another and apparently more recent class less commonly associated with ore deposits in this State; these are,

YOUNGER EXTRUSIVE IGNEOUS ROCKS.

Their leading characteristic is that they have reached the surface and flowed over it like modern lavas and may

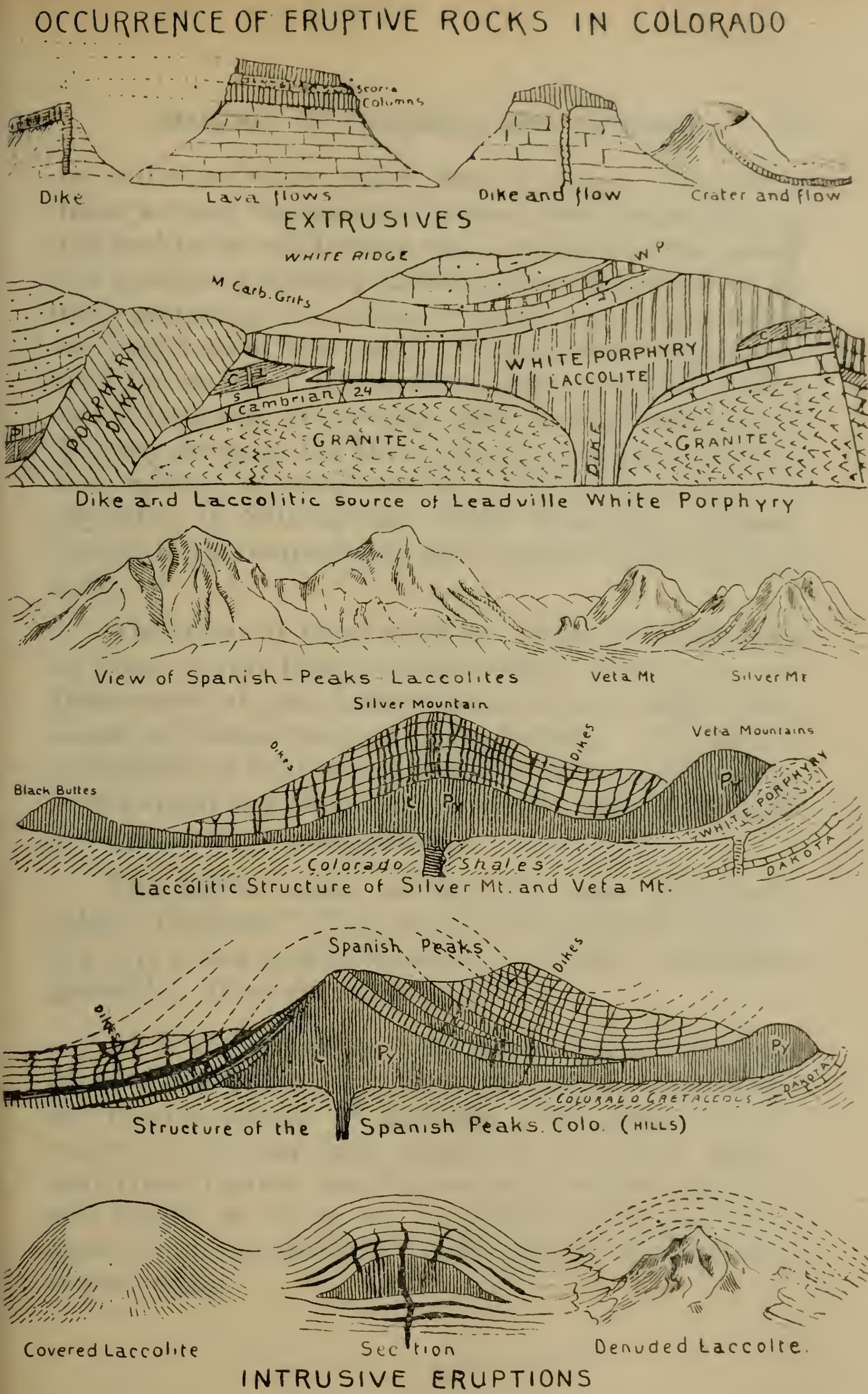

OCCURRENCE OF ERUPTIVE ROCKS IN COLORADO
Scoria
Columns
Dike
Lava flows
Dike and flow
Crater and flow
EXTRUSIVES
WHITE RIDGE
W.P.
M Carb. Grits
PORPHYRY DIKE
WHITE PORPHYRY
LACCOLITE
C
S
cambrian
24
GRANITE
Dike
GRANITE
Dike and Laccolitic source of Leadville White Porphyry
View of Spanish-Peaks Laccolites
Veta Mt
Silver Mt
Silver Mountain
Dikes
Dikes
Veta Mountains
Black Buttes
Py
Py
WHITE PORPHYRY
DAKOTA
Colorado Shales
Laccolitic Structure of Silver Mt. and Veta Mt.
Spanish Peaks
Dikes
Dikes
Py
Py
COLORADO CRETACEOUS
DAKOTA
Structure of the Spanish Peaks. Colo. (HILLS)
Covered Laccolite
Section
Denuded Laccolte.
INTRUSIVE ERUPTIONS

PLATE VII.

be called extrusive rather than intrusive. Typical of these we may cite the dark dolerites and basalts that cap our coal fields and Tertiary and Cretaceous strata along our foothills, frequently forming mesas or table lands by their protecting cap of lava, or appearing in steep ridges or sharp conical hills called "buttes" where their dykes only are exposed. The andesite forming Buffalo Peaks, South Park and the tufaceous pink rhyolite capping the Tertiary mesas on the Divide between Sedalia and Colorado Springs, so much used for building stone, and the rhyolites of Nathrop and Chalk Mountain, Kokomo, belong to this extrusive or more modern type of igneous rock.

The colors of these rocks are either very dark gray or black, or very light, and even white. In the one case they consist of dark, heavy minerals such as augite, magnetite and feldspar and are said to be basic. In the other, principally of light minerals, such as feldspar and quartz, with a sprinkling of mica or perhaps a little hornblende or augite and are called acidic.

The lighter rocks are popularly and erroneously called "trachytes." They are mostly rhyolites, as trachyte is a very scarce rock in Colorado or in these mountains generally. It occurs at Silver Cliff.

At Nathrop station, near Buena Vista and Chalk Mountain, Kokomo, and Black Mountain, South Park, are good examples of rhyolites. The great eruptive region of the San Juan appears to consist of quartz-porphyries, diorites, porphyrites, some andesite, rhyolites and basalts so far as we at present know, and there appears to be an older and a newer series of igneous rocks in that region.

TYPICAL PORPHYRIES AND ERUPTIVE ROCKS DESCRIBED.

Though there are a great variety of eruptive igneous rocks distinguished from one another by many hard names and subtle definitions, the ordinary mining man need concern himself with but a very few characteristic types commonly met with near the ore deposits of Colorado. We will mention some of these and roughly define them.

They are quartz-porphyries, porphyrites and diorites.

A quartz porphyry is a porphyry that contains quartz crystals, large or small, in addition usually to large crystals of orthoclase feldspar, generally of a vitreous or glassy variety called "Sanidin," together with small crystals of hornblende or mica. We will take that which forms the dyke on Mt. Lincoln, South Park, as a type. It is called Mt. Lincoln quartz-porphyry.

In appearance it is a gray rock, spotted with large crystals of orthoclase-sanidin feldspar, which sometimes shows an oblong face two inches long by nearly an inch wide, at other times a shape like the gable end of a house, according to which part of the crystal is exposed. Sometimes two crystals are seen locked together, forming what are called Carlsbad twins. When the rock is decomposed these crystals not unfrequently fall out, and lie as pebbles on the ground. With these may also be seen the ends of bluish or pinkish crystals like broken glass. These are portions of quartz-crystals which, when extracted perfect from the rock, show a six-sided pyramid at either end. These large crystals are set in a crystalline paste of smaller crystals of the same kind, together with many little black cubes of shining mica or duller lustred and longer rectangular oblong crystals of hornblende.

This porphyry is eruptive and intrusive, occurring in dykes and intrusive sheets and laccolites. In the South Park region around Mt. Lincoln, and in the Gunnison region, around Crested Butte and Gothic, it is exceedingly common, as well as in many other localities in Colorado. In Leadville there are several varieties of much the same class of rock.

LEADVILLE WHITE PORPHYRY.

At Leadville there is a quartz-porphyry known as the Leadville white porphyry, or "block porphyry," by the miners, which needs description, as it is the one that commonly overlies the rich ore deposits. It is a white, compact, homogeneous looking rock, not unlike a shaly white sandstone, limestone or quartzite. It consists of feldspar, quartz and a little mica. Its porphyritic or spotted character is so indistinct that one would hesitate to call it at sight a porphyry, but the microscope reveals perfect double pyramids of quartz and perfect individual crystals of feldspar set in a paste of the same minerals. It is often stained by concentric rings of iron oxide and marked with wonderful imitations of trees. The latter have earned for it the title of "photographic rocks." These markings are only the crystallization forms of oxide of iron or manganese, something after the manner of fern frost work on a window pane, and are called "dendrite," or tree rock. This porphyry is very shaley and breaks off into thin blocks, hence its name locally of "block porphyry." It is an eruptive, intrusive rock, occurring in dykes, laccolites and intrusive sheets. It is common at Leadville, but not so much so in other parts of Colorado. There are several other quartz-porphyries akin to these, such as the gray porphyry, the Sacramento porphyry and the pyritiferous porphyry. The latter is so named from its being everywhere highly charged with minute particles of iron pyrites. It is not improbable that a good deal of the gold of this region came indirectly from this porphyry.

PORPHYRITE AND DIORITE.

These two rocks are so nearly alike in their mineral composition, mode of occurrence and appearance that we class them here as one. They differ from quartz-porphyries mainly in the fact that their feldspars belong to the plagioclase instead of the orthoclase variety. Hornblende also is a main constituent of these rocks and gives them their general dark gray or greenish tint. The appearance of diorite is not unlike that of granite or syenite, but its mode of occurrence as an eruptive, intrusive rock distinguishes it from the latter. Quartz is also present, so their general composition may be plagioclase—feldspar, quartz and hornblende. Mica, too, may or may not be present. A porphyrite appears to be little more than a porphyritic or spotted diorite. The plagioclase crystals are much smaller than the orthoclase feldspars of the porphyries and generally of a glassy white color. A hand specimen of porphyrite might readily be mistaken for granite, but its spotted appearance can generally be detected, distinguishing it from the latter. Hornblende decomposing gives these rocks an olive green color, hence their name of "green stones."

Porphyrite may be observed forming intrusive sheets in the walls of several of the cañons of South Park, such as Buckskin or Mosquito cañon.

Diorite constitutes some of the principal eruptive peaks of the Elk Mountain range, such as White-rock Mountain, and the rocks along Copper Creek near the Sylvanite mine. A great mass of quartz-mica-diorite


CRYSTALLINE ROCKS
1
Felsite Porphyry
2
Mt Lincoln Quartz Porphry
3
Leadville White Quartz Porphyry
4
Porphyritic Diorite (Porphyrite)
5
Syenite
6
Granite
7
Gneiss
8
Contorted Mica Schist
9
Quartzite (part magnified)
10
Pegmatite
11
Rhyolite Lava
12
Andesitic Breccia
13
Amygdaloidal Scoria
14
F
Q
Q
F
F
Orthoclase - Feldspar & Quartz
15
H
A
Mg
G
M
Hornblende. Augite. Mica
Magnetite, Garnet

PLATE VIII.

much decomposed and spotted with iron pyrites overlies the ore-bearing limestone in Vallejo gulch, in Aspen Mountain, and is traceable for many miles in the direction of the Elk Mountains, from whose eruptions it was doubtless derived.

These are the principal eruptive intrusive rocks met with in our mining districts. Of the eruptive extrusive or surface flowing lavas such as Andesite, Rhyolite, Trachyte, Dolerite and Basalt. These are all of more recent date than the last. Andesite is very abundant in the lava flows of the San Juan region. There it forms enormous masses of "volcanic breccia," that is, masses or flows composed of angular fragments of Andesite lava, cemented together by a lava paste. The blocks are commonly of a pinkish or lilac hue, whilst the paste is often an olive green. In this breccia occur most of the fissure veins in the San Juan. Andesite lava has a fine grained compact and sometimes vitreous paste or matrix compound mainly of oligoclase feldspar, in which are scattered about black crystals of hornblende or augite, with numerous little white crystals of oligoclase feldspar called Andesine, because first noticed in the Andes. The rock has generally a fine grained compact appearance of a lilac purple, maroon or dark gray color, spotted with the porphyrite little feldspar crystals. The rock is sometimes an olive green from the oxidation of the hornblende into a chloritic substance. The regions of Cripple Creek, Silver Cliff and Creede are characterized by these rocks as well as the San Juan generally.

Rhyolite, characteristic of Silver Cliff and Creede, is usually a rock light in color and light in weight, pale pinkish, pale gray or white; often it is compact and shows a finely laminated strueture, as if fine drawn layers of molten matter had flowed over one another. Some rhyolites of this kind are not unlike petrified wood. A variety of rhyolite called Nevadite is coarsely granular, characterized by a great number of distinct smoky quartz crystals and glassy sanidin feldspars, set in a finer, even-grained groundmass of quartz and feldspar. Chalk Mountain near Leadville and Nathrop near Buena Vista are of this Nevadite.

Trachyte is so rarely met with in Colorado, the only mining locality known being at Silver Cliff, that we omit further mention.

Dolerite does not occur in Colorado connected with any important mines, but is common on the table mountains and foothills. It is a dark gray rock composed of crystals of augite and magnetite, and labradorite feldspar, in a fine groundmass of the same constituents. Basalt is only a finer grained variety in which the crystals are less distinct. These surface flow rocks often assume a columnar, a scoriaceous or vesicular spongy structure.

METAMORPHIC ROCKS.

There is another class of rocks, however, which the miner meets with, which are generally more or less crystalline in character but are neither eruptive nor intrusive. Their crystalline character, however, shows that they have been subjected to a certain amount of heat. These are called metamorphic or changed rocks, because they were originally common sandstones, shales or limestones, such as we find underlying the prairie, and have been partially changed or metamorphosed by heat into a crystalline condition very unlike their original one. To this class belong granite, gneiss, schist, syenite, quartzite, slate and marble, and we might add anthracite coal and graphite.

Granite, as we have said earlier in this treatise,* may have been a sort of sedimentary rock, such as sandstone, its materials derived from the sand washed from the primitive crust of the earth. By heat, pressure, alkali, and other chemical ingredients, it has been changed into the purely crystalline rock we find it, and without being entirely fused like the lavas, it seems to have been softened by agueo-igneous fusion to such a degree that it has lost even its signs of stratification and appears massive. We find few evidences in Colorado of its being truly eruptive. It never occurs as a dyke penetrating the overlying limestones or sandstones or in intrusive sheets amongst them as the porphyries do.

It appears to be the bed rock of the world, underlying our prairies and the foundation of our mountains, and was, as we have said, the shore line upon which our sedimentary rocks were deposited. Gneiss is simply stratified granite; *i. e.*, granite that has not been so completely metamorphosed and softened as to entirely lose the signs of its primitive bedding and stratification. It is not structureless, therefore, and massive, like granite.

Syenite is much the same as granite, only hornblende takes the place of mica. Granite is composed of mica, quartz, and feldspar. Syenite of hornblende, quartz and feldspar. Mica and hornblende schist is granite or syenite in a finely laminated condition, corresponding to mud shales in the unaltered rocks.

Structureless granite is not so common generally in Colorado as gneiss and schist. A very massive gneiss common in Colorado is called a granite gneiss. Up the Platte cañon granite is finely represented in Dome Rock and the Cathedral Spires. The Sawatch range is princi-

*NOTE—We have alluded before to the difference of opinion on this subject.

pally granite. As a rule it is commoner in the heart of the mountains than near the flanks, as might be expected, since it is the deepest buried rock in the last condition of metamorphism. Its common colors are reddish from the color of feldspar, or gray from the predominance of mica. It is much traversed by veins of all kinds, principally quartz or feldspar, or both combined. Such combinations when there is little or no mica, are called "pegmatite" veins and it is such veins that form the matrix of most of our ore-bearing fissure veins in granite, such as those at Boulder, Central, Georgetown, etc. Granite may be distinguished roughly from porphyry by its non-eruptive occurrence and by its lacking that peculiar spotted characteristic of the porphyries. It always underlies, never overlies any other kind of ordinary sedimentary rock in Colorado.

Quartzite is another metamorphic rock; it was once a sandstone more or less pure, but of more recent age than the granite, as it is generally found lying near upon the Archæan granite, and belonging to some member of the Paleozoic series, such as the Cambrian, Silurian or Carboniferous.

Heat has changed this sandstone into a quartz-rock or quartz-stone very hard and usually pure white or gray, or stained with oxide of iron. The difference between quartz and quartzite is that the latter is a quartz-stone, whilst the former is a mineral. A stone made of fragments and granules of the original mineral quartz, cemented together by liquefied quartz.

In Colorado it may be seen forming long belts as of white masonry or brick walls, in our high mountain districts, lying on top of the granite or in strata between the limestones. As we retreat from the granite and rise into the upper carboniferous the quartzite gradually passes into hard grits and finally into common sandstones of the Triassic or more recent formations, among which few ore deposits are found.

Quartzites may contain both gold and silver-lead deposits, more especially the former. They are hard rocks to mine in.

LIMESTONES.

Our ore bearing limestones are usually of two or three varieties and are mostly confined to the Silurian and Carboniferous or Paleozoic rocks. These are, generally speaking, in Colorado, magnesian limestones, commonly called dolomites. Some few are ordinary limestones of nearly pure carbonate of lime. They are mostly silicious, especially those of the Silurian period next to the quartzites. Nodules of chalcedonic chert or flint are very common in them, and give them a rough appearance where erosion has caused the chert to stand out on the surface. The Silurian limestones are characterized by *white* chalcedonic flints or cherts and by a general pale-yellow, light-gray or drab appearance. The carboniferous limestones above them, by a more massive structure, by the occurrence of *black* chert nodules, and by a dark blue gray color. The Silurian dolomite is locally called "short time" or "white limestone," the carboniferous "blue limestone" for distinction. At a few points in the mountains these limestones have been metamorphosed into marble and serpentine.

Argentiferous lead ores are found in both these limestones, but the Carboniferous "blue limestone" has been the greatest producer. At Aspen the blue limestone is an ordinary carbonate of lime or true limestone above, passing into a dolomitic or magnesian state below. The ore occurs penetrating both forms of the limestone.

Outside of these characteristic rocks comparatively few deposits of importance have been found in Colorado. Hence prospecting has yielded little in the upper Carboniferous grits that overlie the productive limestone. An exception occurs, however, at Kokomo, where the Robinson mine has been a large producer in a belt of true limestone in the upper part of these grits. The region around Crested Butte and Irwin is also another exception, where, as we have said, fissure veins penetrate through all the formations alike.

PREJUDICE IN FAVOR OF AND AGAINST CERTAIN ROCKS.

There is often a prejudice amongst miners in favor of certain rocks and formations, and against others. Miners who have worked perhaps in the great Comstock mine of Nevada, or the Leadville mines of our own State, or the fissure veins in granite of the Old World, are apt to look out for and favor certain rocks and formations they find like those they have been accustomed to. Thus, as Mr. A. Williams, Jr., says, "The peculiar 'porphyry' of the Comstock was hunted up in other districts, but did not prove metalliferous. Solid granite was looked upon by others as unfavorable, generally, because locally some granite above the gold belt of California had proved barren. Yet some of our best veins are in granite.

"Limestone was at one time a very unpopular rock and supposed only locally to produce lead, till the discoveries of Leadville and Eureka, Nevada, overturned the scale in its favor."

In the Leadville "excitement" not only was the particular Carboniferous limestone of Leadville hunted for and prospected, but every other limestone in the South Park region, no matter what its geological age or position, was extensively prospected without results, miners not recognizing the fact that it was not limestone generally that produces rich ores, but a *particular* limestone of a *particular* geological period (the lower Corboniferous), not over 200 feet thick, that happened locally to be rich near Leadville, and the reason of its being locally rich at that point was owing to the concentration of *eruptive energy* at that point and the intrusion of an unusual amount of porphyries, which in point of fact are far more responsible for the ore than the limestone, which happens to be merely the receptacle.

It was also quite common after the Leadville excite ment to find shafts in all sorts of improbable and hopeless localities whose owners would tell you: "At Leadville it didn't matter where a man 'went down.' It was all luck whether you 'struck it' or not, and so they might as well 'go down' where they were as elsewhere." It was often said "that Leadville had exploded all so-called scientific theories about ore being in one formation or locality more than another. It was all a case of luck."

The excuse for this is to be found in the fact that in the immediate vicinity of Leadville it did scarcely matter "where you went down," seeing that that area was practically underlaid by bedded sheets of mineral, but that such would be the case elsewhere and everywhere or anywhere, experience unfortunately has shown to be untrue. It is not a particular rock or formation, but a combination of favorable circumstances that alone can make a rich mining district.

As experience advances geologists and miners have proved that ore deposits have a much wider range than was once supposed. Formerly only the Archæan granite series was supposed capable of bearing ore deposits, because in the Old World, tin, copper and lead came principally from fissure veins in those rocks. Then deposits were found in the Paleozoic series and supposed to ascend no higher. But in the present day, and even in Colorado, they are traceable even to the Tertiary.

It is not the rock, nor the age, but a combination of circumstances, principally heat and metamorphism, that may make any rock of any period an ore-bearing one. And in prospecting in new regions it is these combinations rather than any particular rock that should be looked for.

STRIKE AND DIP OF COLORADO VEINS.

The dip of veins in Colorado approaches more nearly the vertical than the horizontal, usually from 75° to verticality. Nearly all our ore deposits, even those of the bedded class, dip more or less steeply from 25° to 75°.

For a few feet from the surface, on the steep slope of a mountain, it is common to find an ore deposit dipping quite gently or even folded over in a contrary direction to that which it assumes with depth. This appears to arise from the weight of the strata above it tending to bend it over downward in the direction of the slope of the hill.

There is generally a prevailing dip and strike amongst a number of parallel fissure veins of a district. In the San Juan, the bulk of the fissure veins have a prevailing north-easterly strike and a dip to the south-east. The angle of dip is generally between 60° and vertically.

CROSS-CUTTING UNCERTAIN.

The dip, as we have said, not unfrequently changes considerably with depth, usually becoming more and more vertical. From the degree of uncertainty as to the continuity of the dip, it is not always safe, on the discovery of an outcrop, to endeavor to cut it at a much lower point, so as to get the coveted depth, and better opportunities for stoping, drainage and other developments of the mine. Owing to a change of dip or fault, perhaps, the miner may have to make a much longer cross-cut tunnel than he had calculated upon before striking the vein. Sometimes, too, he may miss the vein altogether, cutting it perhaps at some point where it is exceedingly thin or poor, so poor in fact that he passes through it without noticing it, or believing it to be the same vein whose outcrop looked so promising on the surface. Cross tunnels through "dead rock" should hardly be undertaken until the vein has been proved to be a strong one for a considerable depth. As we have already shown, great depth may not after all be so desirable in even a fissure vein, as there is no certainty whatever about veins becoming richer or poorer with depth. Extensive cross-cut tunnels have seldom proved paying concerns. The greatest in the United States, the Sutro tunnel, six miles in length, which tapped the Comstock fissure at a depth of 2,000 feet, did not prove a financial success, and had it tapped the fissure still lower, at 3,000 feet, it would have found the vein in the impoverished condition it is to-day. It is not uncommon for a miner to strike a rich outcrop on the top of some mountain, and on the strength of its richness induce a company to run a long cross-cut tunnel in "dead rock" half through the mountain to cut this vein, and the company's resources are nearly exhausted in so doing, while the vein itself gives no returns, owing to its being left idle. Finally, perhaps, the vein is missed, or if struck, proves far poorer than was anticipated. Of course there are exceptions where cross-cut tunnels in "dead rock" may be advisable.

If a fissure vein, as in the San Juan, should outcrop near the top of a mountain and be exposed on its dip all the way to the bottom, there may be some reason for opening a tunnel in it near the base, thereby facilitating drainage, development and exportation. In that case the miner is *on* the vein, with no fear of losing it; but even here, there is no guarantee that it will prove rich all the way to its outcrop a thousand feet above. "Follow your ore," is a common and wise saying among experienced miners, "and be careful how you leave it for any experimental theories." We remember a tunnel in the Gunnison region which was run several hundred feet at a cost of many thousands of dollars, all through "dead rock," in the hopes of cross-cutting a certain ore body that had proved rich near the surface. At last it was given up, and subsequently a short cross-cut was made from it, and the original vein was found only a few feet from the tunnel, which had been running parallel with it all the time. The cause of the mistake was an unforeseen fault in the vein that had shifted its dip much further on one side than had been calculated upon.

STRUCTURE OF VEINS.—VEINSTONE OR GANGUE.

In most ore deposits, whether they be called fissure veins, true veins, gash veins, blanket veins, or by whatever name they may be designated, the space between the confining "country rock" or "walls" on either side is occupied by "gangue" or veinstone, consisting generally of some of the elements of the adjacent country rock in an altered or more sparry condition than in the parent rock.

The commonest of these veinstones is *quartz*, which is usually massive or of coarse or fine crystalline structure. In the San Juan region it is commonly a very fine-grained, hard, jaspery material, of a blue-gray color; in other places coarsely crystalline, like loaf sugar, and frequently contains beautiful little cavities called "vughs" or "geodes" or "drusy cavities," lined with long, perfect quartz crystals. In the San Juan these cavities are most abundant toward the center of wide mammoth veins.

Lime is a common veinstone or gangue, particularly in limestone districts. It is in a white or yellowish crystalline condition, the crystals assuming various forms, or forming a crystalline mass. Crystalline dolomite also occurs in the dolomitic limestones of Leadville and Aspen. Stalactites of arragonite, another form of calc-spar, are characteristic of the cavernous openings found associated with lead ores in limestone.

At the Silver-islet Mine, Pitkin County, in the Sacramento Mine, South Park, and in several of the Leadville and Aspen mines, such caverns lined with stalactites occur. These caverns appear to have been formed after the deposition of the ore bodies, since they are hollowed out of limestone and ore bodies alike, by surface waters, which, descending through the natural jointage planes in the limestone, have by the assistance of carbonic acid, enlarged those jointage cracks and eventually formed caverns, either in them or in the lines between the stratification planes.

A beautiful rose-colored carbonate of manganese called *rhodocrosite* is found in the gangue of some of the mines of San Juan and South Park. In South Park at one locality it is associated with quartz in a vein in granite.

Fluor Spar, one of our softest minerals of a pale green, sometimes of a purple color, occurs in fissure veins in the granite rock. In Bergen Park a deposit occurs of sufficient size for development for flux for the smelters. The white Cretaceous limestone of the plains has of late superseded its use.

Baryta occurs as a veinstone associated sometimes with lime crystals in the limestône districts, such as Aspen, Leadville and South Park, where those limestones have been penetrated by eruptive porphyries. While veins of calcspar, common enough throughout the limestone rocks may or may not locally indicate the presence of mineral, the presence of baryta is a pretty sure indication of a mineral lead. It is a significant fact showing the relations of ore deposits to porphyry that baryta is detected as an element in the feldspars of certain porphyries.

Baryta, though resembling calcspar, can be distinguished from it by its greater heaviness, its not effervescing with acids, its emitting a green flame and "decrepitating" or flying to pieces under the blow pipe. Its lustre is more pearly than ordinary calcite. As it usually occurs massive, its different crystallization is not always to be seen.

Baryta is not confined to limestone regions, for we find it forming the gangue in several mines in the eruptive rocks of San Juan, notably at the Bonanza Mine on the shore of Lake Como, where it is associated with a good deal of gray copper. In Hall's Valley it occurs in a vein in gneiss also associated with rich depcsits of gray copper.

It is a refractory substance in smelting processes and troublesome if in excess.

With these veinstones is a good deal of oxidè of iron, and sometimes oxide of manganese, together with carbonate of copper stains. Carbonate of iron in the form of spathic iron or siderite very like orthoclase feldspar in appearance, only heavier; occurs in the gangue of the Whale and Freeland Mines at Idaho Springs.

The surrounding country rock generally determines the character of the gangue. Thus limestone yields carbonate of lime for veinstone, granite its elements of quartz or feldspar, or both combined in what is called "pegmatite" or granulite. The porphyries yield a clay composed of the elements of their feldspars and some quartz; they also seem responsible for the baryta.

The gangue so far from being a foreign substance derived from unknown rocks in the bowels of the earth and filling a fissure through ascending solutions, is on the contrary immediately derived from the adjacent country rock, and often consists of little more than a slight alteration or decomposition of that "country rock" along a crack, fissure, or other line of weakness. Sometimes the gangue is a porphyry dyke more or less decomposed or highly charged with pyrites lying between walls of granite or some other country rock.

DISTRIBUTION OF ORE IN THE GANGUE.

Through these "gangues" of various characters the precious metal is distributed in long narrow patches or strings or in large crystalline masses, or in isolated or scattered crystals, or in decomposed masses.

The gangue matter is generally in the majority and the ore thinly, sparingly and irregularly distributed in it. When a vein is said to be ten feet wide, it is not to be supposed that ten solid feet of mineral from wall to wall is meant, but that, that is the width of the gangue, while the ore body may occupy but a few inches of that width, or be sparsely scattered over it, the remainder being quartz or some other veinstone.

It is common to find one or more rather defined and continuous streaks or courses of ore having a tendency to keep near one or the other wall, or at times to cross from wall to wall. This is called the "pay streak," and is the main source of profit in the mine.

HIGH AND LOW GRADE ORES.

In gold veins, flakes or wires of free or native gold occur in the decomposed gangue, and sometimes in the pure undecomposed quartz. Native silver is found in the same way, but more as cabinet specimens than in any continuous body. Isolated patches of very rare or valuable minerals, such as ruby-silver, horn-silver or silver-glance, occur locally in parts of the vein, or sometimes line the stalactites or crystals of some "vugh" or drusy cavity. An assay of such picked specimens would, of course, give a very unfair average of the mine. As a rule, the bulk of the profits of a mine are derived from the common minerals, such as galena or pyrites, and the secondary products of these, such as carbonate of lead or iron oxide. It is from the ores, too, of comparatively low grade that the steady annual profits of a mine are derived. In California gold mines the average yield of gold per ton was $16. In Dakota $6. In the silver mines of Leadville the average to the ton is rarely more than $40, and the bulk of the ores of that richest of camps is generally of low grade. There are a few mines of extraordinary high grade in sufficient quantities to yield from $75 to $100 per ton, such as some of the mines of Aspen, but these are exceptions rather than rules, and even these have a large quantity of low grade ore on hand. Quantity of ore and facilities for milling, and the size of the vein and its facility for work, or its nearness to market, give the offset.

DECOMPOSED ORES.

Sometimes the gangue matter contains a variety of decomposed ores in rich secondary combinations intimately mixed through its mass, and rarely discernable by the naked eye. Thus a mass of seemingly yellow mud may be found by assay to run high in silver from the concealed presence of chlorides or sulphurets of silver in it. No accurate estimate of the value of a mine or even of a piece of ore can be formed without an assay or a mill run being made. A vein may appear sparkling with masses of galena or glittering with golden pyrites, and seem to the unexperienced a perfect bonanza of wealth. The assay or mill run value may show the galena to be very poor in silver or the pyrites to yield no gold. On the other hand a mass of heavy rusty dirt may assay up into the thousands. The reason for such richness in decomposed surface products appears to be, that nature has been for ages leaching out, concentrating and combining in richer forms the essence, so to speak, of the vein. A rich mine in the San Juan ships nothing but yellow mud, and another, the National Belle, at Red Mountain, yielded similar material when we visited it, which had to be dried before shipping, but gave steady and good returns. It is evident then, how unsafe it is to judge of a mine by the sight alone. Truly "all is not gold that glitters," and the necessity of a thorough assay or mill-run when possible, of portions of every accessible part of the vein, and especially of those poorer portions which yield the daily average, is obvious before the real value of a mine can be estimated.

GRAY COPPER.

Besides the ordinary galena and pyrites we often find considerable bodies of *gray copper* intermingled with other ores. This is nearly always a rich ore, varying, however, in different localities from 60 oz. silver to several thousands per ton. It occurs generally in the massive state, rarely showing its pyramidal "tetrahedrite" crystals.

In appearance it is not unlike a freshly broken piece of bronze. It is more common in the fissure veins in the granite and eruptive rocks than in limestone deposits. In Hall's Valley it is associated with baryta in a vein in the gneiss. It occurs in the Georgetown veins in granite. In the San Juan district it occurs also associated with baryta in the Bonanza mine, and an ore not identical with it in composition, but very like it in appearance, called bismuthinite, consisting of bismuth, antimony, copper and silver, is characteristic of that region and is rich in silver. Bismuthinite has a more shiny, tin-like appearance than gray copper, and the red color which bismuth gives to charcoal under the blow-pipe readily distinguishes it from gray copper.

LOCAL VARIATIONS IN VALUE OF ORES.

There are locally in different mining districts considerable differences in the value of certain minerals and ores. In one district gray copper may rarely exceed 60 ounces of silver, in another it is invariably over 100 ounces.

A coarse galena is penerally poor in silver, while fine grained "steel galena" is generally rich in silver, but the reverse may also be the case. In some of the mines at Aspen fine grained galena, especially near the surface, is quite poor in silver, while in other mines in the same district it is exceedingly rich. Localities occur also where coarse grained galena runs well in silver and is richer than fine-grained galena. This is the case at the Colonel Sellers mine at Leadville. So one mining district or even one mine is not a rule for another.

PYRITES.

Iron pyrites and copper pyrites, common in most of our quartz veins in granite and in eruptive rocks, may yield both gold and silver, but usually the former. There are certain districts more characterized by pyrites than others, such as the Central City district. These are generally gold-producing districts. Some of the mines of Breckenridge and South Park have strong pyritiferous veins in eruptive dykes, such as the Jumbo mine. These have of late produced a great deal of gold. The same district, however, produces large argentiferous lead veins. Pyrites generally favor the granite, eruptive and crystallized rocks. The quartzite of the lower Silurian of South Park and Redcliff are often pyritiferous and generally gold-bearing. In limestone the pyrites is rare or absent, its place being fiilled by some form of iron oxide. In the deeper mines of Leadville, however, this iron oxide is beginning to pass down into the iron sulphide or pyrite from which it was derived. Iron pyrites can generally be distinguished from copper pyrites by its paler, more brassy color, by its superior hardness, and by its crystallizing in cubes. Copper pyrites is much yellower and softer, and crystallizes in a more pyramidal form. A vein may glitter with showy pyrites and yet be quite valueless. It usually yields more gold in its decomposed, oxidized condition, than in its unaltered state. In the one case the gold is free milling, and in the other it must be smelted or chloridised at much greater expense.

"SULPHURETS."

This term amongst miners is loosely used, and often means some decomposed ore whose ingredients cannot be determined at sight, but which somehow assays high in silver. True sulphuret or sulphide of silver is a name embracing a large family of rich silver ores, among which are "stephanite" or "brittle silver," "argentite" or "silver glance," "sylvanite" or graphic tellurium, and "polybasite."

All these rich ores are compounds of sulphur and silver and other ingredients in varying proportions. They are somewhat alike in appearance and not always so easy to distinguish.

Argentite, silver glance, or sulphuret of silver, is of a blackish, lead-gray color, easily cut with a knife, and consists of an aggregate of minute crystals. Its composition in 100 parts is sulphur 12.9, silver 87.1. Under the blow-pipe it gives off an odor of sulphur, and yields a globule of silver.

Stephanite, or "brittle" or "black" silver, is closely allied to argentite. Its composition is sulphur, antimony and silver, silver being 68.5 per cent. The crystals are small. Under the blow-pipe it gives off garlic fumes of antimony. Yields a dark globule from which, by adding soda, we get pure silver.

Polybasite, common at Georgetown and in some of the Aspen mines, such as the Regent or J. C. Johnson, on Smuggler Hill, is like the others, but of a more flaky, scaly and graphitic appearance. It is not unlike very fine-grained galena, yielding 150 to 400 ounces of silver per ton.

These sulphurets sometimes line little cavities in limestones with a dark sooty substance, which under the microscope prove to be crystals of one of the sulphurets of silver. Sometimes also a rock is stained all through a blackish gray by these sulphurets. Iron or manganese may produce much the same effect, but an assay will soon reveal the difference. Associated with such a rock we may see flakes or wires of native silver that have emerged from the sulphide state.

CHLORIDES.

Chloride of silver, "horn silver" or cerargyrite. This is another result of secondary decomposition from a sulphide state, (silver sulphide.) It is a greenish or yellowish mineral, like wax and easily cut with a knife, it is a very rich ore running 75.3 per cent. silver, the remainder being chlorine. As a secondary product of decomposition it is generally found near the surface or in cavities, sometimes deposited on calcite or other crystals. In the mines of Leadville it is commonly associated with other decomposed ores such as carbonates. In the Chrysolite mine, a mass weighing several hundred pounds was found. Chloride, bromide and iodide of silver are closely related, being compounds of chlorine, bromine, iodine and silver. It is noticeable that these salts are the elements of sea water, and that these ores are often found in marine limestones. According to Mr. Emmons the change at Leadville from sulphide to chloride was produced by surface waters; these waters are found to contain chlorine, which they probably derived from passing through the dolomitic limestones which contain chlorine in their crystals and these limestones perhaps originally derived it from the sea water in which they were deposited. Chloride of silver is found at Aspen and abundantly in the out-crop of mines in New and Old Mexico.

SULPHARSENITES.

Ruby silver, (pyrargyrite and proustite.) Composed of sulphur 17.7; antimony 22.5; silver 59.8=100. Crystallizes in rhombohedrons is seen in spots or crystals on a mass of ore of a deep red or blackish tint. When scratched with a knife it shows a bright or deep red color. In some mines this very rich ore occurs only as specimens but in others it is present in sufficient quantity to largely influence the value of the ore in bulk. In parts of the Granite Mountain Mine in Montana it constitutes the principal ore, associated, however, with other mineral. It there occurs in large masses and accounts for the extraordinary richness of that celebrated mine. Proustite is much the same only lighter red and consists of sulphur 19.4; arsenic 15,1; silver 65.5=100.

CARBONATES.

This term also embraces a large family, the commonest being carbonate of lead, (cerussite) and carbonate of copper, (malachite and azurite.)

Copper carbonate can never be mistaken owing to its brilliant green and azure blue color. Copper stains are among the common surface signs of a "lead." It is generally associated also with rusty stains. Both are the surface products from copper and iron pyrites forming a vein below ground which may or may not be profitable. Copper stains are common enough in many rocks, but do not always lead to bodies of ore. In South Park the red Triassic sandstones are so stained, but yield no ore. Along our foothills there is quite a stained belt from Golden to Morrison and through Bergen Park. But few promising deposits of copper or other ores have been found, although handsome specimens of native copper have been discovered near Golden.

At the Malachite mine on Bear Creek, near Morrison, a prospect was at one time opened showing a good deal of silicate of copper (chrysocolla) and malachite, but for some reason it has not been worked since.

Copper in its native or uncombined state is rare in this State, and so far we have as yet no true profitable mine. A great deal of copper is found associated with other ores, and is extracted by some of the smelters. Carbonate of copper is commonest in the limestone districts as might be expected from the carbonating influence of limestone upon minerals in it, or mineral solutions passing through it. Carbonate of iron (spathic iron or siderite,) constitutes part of the gangue matter in some of our veins, and may also be found associated with coal seams generally, in the latter case in an oxidized condition.

Carbonate of lead (cerussite). This is mostly found in the limestone districts, such as Leadville. It is there known in two forms, one called "hard carbonates," the the other "soft" or "sand carbonates." The crystals of this ore are small prisms, sometimes combined into a cross shape, of a pale grayish white, and might be taken for some form of carbonate of lime or gypsum, their weight, however, soon shows the difference. They are a secondary product of decomposition consisting of carbon dioxide and lead oxide, as a carbonate they effervesce in nitric acid, and yield lead when heated. Cerussite is exceedingly rich in lead, carrying 75 per cent. The white lead of commerce has the same composition. In Leadville and elsewhere in Colorado it is silver-bearing also, and though low in silver, the facility of its treatment at the smelter makes it a very desirable ore. As a rule it contains less silver than the unaltered galena, but is more easily treated than the latter. The process of change or derivation from a sulphide state (*i. e.*, from galena) to a carbonate, is well shown sometimes in a piece of Leadville ore. A central cube of galena is surrounded by a grayish green ring of sulphide of lead or anglesite, and outside this may again occur crystals of lead carbonate. Thus the process is from a sulphide to a sulphate, then to a carbonate. The so-called "hard carbonates" is a brown mass consisting of a hard flinty combination of iron oxide and silica, impregnated with crystals of lead carbonate, with which are often silver chlorides, also.

The "sand carbonates" result from the decomposition and breaking up of the "hard carbonates," or from a mass of pure crystals of carbonate of lead, which are, by nature, loose and incoherent. The Leadville mines are getting below these products of decomposition and entering upon the original sulphides of galena and iron. The yield, however, is said to be equally good.

ZINC BLENDE (SPHALERITE), "BLACK JACK."

Common in most mines mixed with other ores. As it is a very refractory mineral in smelting, much of it is not desirable in a mine.

It is easily recognized by its brown resinous look or when very black by its pearly lustre. At Georgetown, near the surface, brown "rozin zinc-blend" carries silver, and it is associated with rich ores, such as polybasite and gray copper. With depth the zinc-blende becomes more abundant and blacker, and loses much of its silver properties. Zinc-blende may run from nothing to twenty dollars silver, and rarely as high as $100 per ton.

In some mines in the San Juan it occurs abundantly near the surface and fades out at times with depth. We have no true zinc mines in this State, the zinc being mixed with other ores. In some mines in Pitkin County the zinc predominates over all other ores, and though it runs high in silver the smelters do not care to take it, on account of its refractory character. In the Eastern States where zinc smelting is a specialty such ore might be separated and both silver and zinc saved.

In Colorado there are no mines of one mineral alone, as in some other parts of the world. We have no true lead, zinc or copper mines; these baser metals are either argentiferous or auriferous, and their baser qualities are sacrificed for their richer ones.

"BRECCIAS" AND "HORSES."

Some lodes enclose fragments of the country rock. When these are small and angular the vein is said to be "brecciated;" when they are large so as to split the vein they are called by miners' "horses."

Breccia usually occurs in large veins near the walls. This is frequently seen in the fissure veins of the San Juan region. Fragments of the adjacent eruptive rock are enclosed by a bluish quartz.

In the same region, where we have extraordinary opportunities of seeing complete sections of great fissure veins descending the face of a cliff for 2,000 feet, on either side of a profound cañon, a broad vein is at intervals observed to split up into two or three arms enclosing large fragments of the "country rock," and these are then seen to unite again in a broad vein, which at another interval will again include a large "horse," or split up into a number of branches, which again unite to form the main vein. See plate No. IX.

These veins occupy a once shattered fissure, the walls of which are neither straight nor regular, but shattered either into small fragments near the vein, or into large ones extending into the country rock. The vein material has insinuated itself in between the shattered portions, sometimes enclosing small fragments and producing a "breccia;" at others around large fragments, producing a "horse." Sometimes the brecciated fragments are surrounded by rings of ore, and are called "cockade ores."

SUBSTITUTION BY SILICA.

Quartz substitutes itself for other mineral elements or portions of the country rock, as matter in a wounded limb substitutes itself in the place of the natural flesh. Rocks have been wounded by narrow cracks; these cracks have been healed by siliceous matter oozing or supplied from the adjacent rocks in solutions; the solution matter not only heals the crack, but eats into and substitutes portions of the country rock on either side the original fissure with its own matter; and so, we think, are sometimes formed wide fissure veins of quartz, the original crack or fissure being perhaps not an inch in width, but simply a line of weakness for mineral solutions to work upon and exercise substitution. This substitution or 'metasomatic' replacement is not unlike that which takes place in the fossilization of a tree-trunk. A tree falls into a marsh, is buried in mud and sealed from contact with the air. It is soaked with water carrying silica in solution; as the cells of woody fibre gradually rot and pass away each molecule of wood is replaced by a molecule of silica. The result is a tree substituted or replaced by silica, or as we say, a silicified, fossilized trunk. So breccias may be sometimes formed by quartz substituting itself for portions of the country rock, leaving harder or unchanged portions not yet substituted still remaining in the vein surrounded by the quartz. Fragments forming breccias do not seem to have fallen into a wide, gaping fissure, gradually filling up with quartz in solution, and so got entangled in the quartz, for many of the pieces will match one another, and appear rather as if quartz in solution had enlarged slight cracks between the fragments, or else, as we have said, substituted a large portion of the country rock, leaving portions still unsubstituted. "Enclosed fragments of country rock are nearly replaced by silica, leaving only a shadowy image of their original forms."

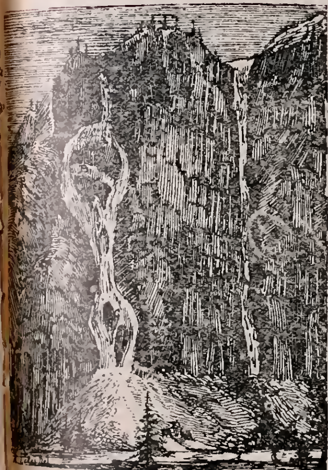


Fig 1 Horses in great Fissure Veins
Animas River Cañon. San Juan Colo
A Fissure Vein, B Horse; C Caves D Tunnels

Fig 2. Horses and Split Veins
Animas River Canon - San Juan. Colo.
A Promontary Tunnels, B Byron Tunnel

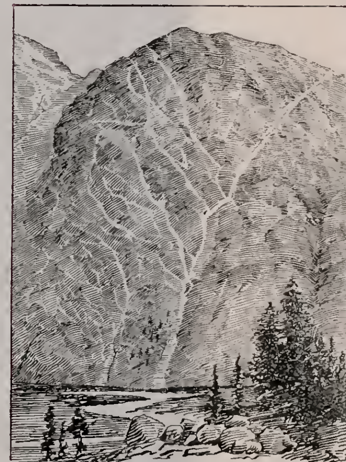


Fig 3 Metalliferous Veins exposed to view
near Howardsville, San Juan, Colo.
Showing 2 Systems of fissure Veins, crossing one another

PLATE IX.

"BANDED, COMBED OR RIBBON" STRUCTURE.

"The various minerals filling a vein fissure are frequently arranged in a succession of bands parallel to the walls. These bands or 'combs' are aggregations of crystalline minerals, the separate crystals of which are usually arranged with their longer axes at right angles to the walls of the lode, while their crystalline form is more perfectly developed at the ends turned towards its center than at the other extremity." These combs meeting, if their crystals happen to be long pyramids of quarts, remind one of two rows of teeth clenching and interlocking.

COMBED STRUCTURE.

"The 'ribbon' or 'banded' structure indicates long-continued chemical action, eccasionally interrupted, but again renewed under different conditions, the substances deposited in the walls varying with the nature of the minerals held in solution at the time the bands were severally formed. Some parts of a vein may show this comb structure, while others show no trace of any particular arrangement." Perhaps the latter case might be due to greater pinching or pressure, not admitting of freedom for crystallization. Toward the center of large quartz veins, "vughs," or cavities of a lenticular shape occur, lined with beautiful quartz crystals, their points pointing to the center of the cavity, at right angles to the wall. There seems to have been an open space here, or a relief of pressure sufficient to allow the quartz to crystallize out in such large and perfect forms. If the vein was filled by "lateral secretion," *i. e.*, by solutions coming from the sides and forming on either wall, there would be naturally a space in the middle. In the basaltic rocks of Table Mountain, at Golden City, cavities have been formed in the molten lava by steam bubbles. These cavities were subsequently lined by a succession of zeolite crystals, first chabasite, on this thompsonite, and lastly analcite. The minerals for these crystals were derived by solutions from the basalt in different degrees of combination, and so crystallizing in different forms. This is probably analogous to the vein ribbon structure. "Fortification" and ribbon agates are of the same nature.

Vein fissures, being a line of weakness, have occasionally been re-opened and a new or different character of veinstone or mineral formed in the interstice, giving rise to a series of alternate "ribbons."

The re-opening of a fissure has been attended by a grinding together of the walls, resulting in slickensides and gouge, and this may account for the appearance of gouge in the center or heart of a vein which has been re-opened.

The arrangement of the minerals in these alternate bands or ribbons could only be produced by solution or sublimation. The successive layers are produced by deposits parallel to the walls, while the crystals have their axes directed to the center of the vein. This banded, ribbon, combed and "vugh" structure is common in the San Juan district.

"In vein fissures," says Phillips, "formed at different periods, the mineral deposits will depend upon the nature of the substances dissolved in the waters circulating through them at the time of their formation. In the same locality the nature of these solutions has changed from time to time, hence the variety of minerals found at intervals in a mine. In nearly all wet mines secondary minerals of various kinds are in progress of formation from the original sulphides of the vein proper." Galena that has been left lying on a dump for many years has been known to pass gradually into a sulphate and thence into a carbonate of lead.

CHANGE OF MINERALS WITH DEPTH.

Lodes often change in the character of their minerals with depth, not only after they have left the zone of secondary decomposition and surface action, but also far below it. Thus, in the San Juan some of the mines abound in zinc-blende near the surface, which with depth almost disappears, giving place to gray copper and other superior ores. In Cornwall, England, the shallow workings yield copper, and with depth, tin; and locally, many such changes may characterize a particular district, but cannot be formulated as a rule for other localities.

INFLUENCE OF COUNTRY ROCK.

In most mining regions, to which Colorado is no exception, a relation has been observed between varieties of "country rock" and ore deposits. Veins in passing from one country rock to another are liable to change in the size or variety of the ore, widening in connection with some rocks, and pinching or growing narrower in connection with others.

Certain rocks are notorious ore-bearers, whilst others are notoriously barren over large regions, or in special localities.

The presence of certain rocks adjacent to other different rocks has an enriching tendency on the ore bodies.

As regards rocks that are good ore-carriers or receptacles of particular classes of ore in Colorado, we may say that quartzites and silicious rocks generally carry more pyrites, and are gold-bearing.

That veins in granite rocks carry a greater variety of minerals than others, and may be both gold and silver-bearing.

That certain limestones carry much argentiferous galena.

That sandstones and other unaltered rocks carry little ore of any kind.

The influence of country rock on veins may be from several different causes, for instance:

Certain rocks are by their structure better adapted than others for forming regular fissures. Thus, massive limestone is better fissured than slate or shale, leaving wider open spaces for the ore to collect in.

Other rocks may be more porous, and admit mineral solutions through their pores. Of such a kind are some of our porphyries.

Others, like limestone, are easily acted upon by solutions dissolving out the rock and replacing it with mineral by substitution.

Some are better conductors of heat, and therefore would assist chemical action and mineral solution.

And lastly, if modern theories of "lateral secretion" be true, viz: that most ore comes from the adjacent country rock and is precipitated, substituted, or collected in the vein fissure, and further, that the metals themselves are derived from certain metallic elements in the ordinary constituent minerals of the country rock, such as mica, hornblende, or augite, it is clear that a rock composed largely of such minerals would be liable to influence the vein as an ore generator. Granite and porphyries are largely composed of these minerals.

The frequent presence of eruptive porphyry rocks near veins and ore deposits in Colorado shows that they have an important influence on those deposits, which may be of various kinds.

First, that in their component minerals and mass they actually contain the elements of the precious metals subsequently deposited in another form, in the fissure vein or in the soluble limestone in contact with it.

Secondly, by the heat which they retain for a long time after they have congealed and hardened, they would assist in the reactions of any chemical or mineral solutions that might be on hand. Lava, at the time of its eruption, is always highly charged with steam and other gases. By reason, also, of the chemical composition of porphyry, waters passing through it would be alkaline and assist in dissolving silica and other gangue or veinstone matter, and when the porphyry has thoroughly cooled it is exceedingly porous, and being much jointed and cross-fractured, becomes like a great sponge for the absorption of all surface waters. This may be noticed at Aspen, where all the mines that are at present penetrating through the "porphyry cap" are much troubled with water, far more so than in the underlying limestone. Surface waters, then, becoming alkaline by passing through this rock, and also more or less charged with carbonic acid, chlorine, and other solvents, would be ready to dissolve both gangue and vein ingredients out of the porphyry and redeposit them in the vein fissure, or, by metasomatic substitution, in the limestone usually beneath it.

Water circulating in fissures changes or dissolves the ingredients of the surrounding rock. The rocks enclosing lodes are always so altered, and this decomposition and alteration is not always merely local or confined to the close proximity of the ore body, but we often find a whole mining district, such as Leadville, Aspen and San Juan, pervaded by this feature. So much is this the case that it is often difficult to get a fresh, unaltered specimen of porphyry or some other country rock within the district.

The brilliant red, yellow and maroon tints that color so much of the mining district of San Juan result from the oxidation of pyrites and other iron-bearing minerals pervading the eruptive rocks, and it is noticeable that this color, resulting from alteration and decomposition, is most prominent in those parts where lodes have been discovered, as, for example, the gorgeous tints of the Red Mountain area around the celebrated "National Bell," "Yankee Girl," and Ironton mines, between Silverton and Ouray. The rocks in Geneva Gulch, Hall's Valley, Buckskin Cañon, and in other mining centers, display the same beautiful tints of oxidation in the vicinity of the mines.

"In lodes a mutual exchange takes place through the reaction of the ingredients of the rock and the materials of the vein. Thus, when water containing carbonates comes in contact with rocks or minerals containing alkalies, a chemical reaction takes place. When these last are combined with silicic acid, these silicates are decomposed by the carbonic acid and the bicarbonates. This explains both the crystallizing out of the carbonates and the so frequent decomposition of rocks containing lodes, especially those which, like our veins of granite, are feldspathic."

The same principle applies to other ores and minerals in lodes. Thus the precious metals in the mines of Leadville in their original condition have been proved by depth to have been in a sulphide state, such as iron pyrites (sulphide of iron), or galena (sulphide of lead), etc. Surface waters charged with carbonic and other acids, passing through the overlying porous alkaline porphyry and entering the underlying limestones, have, as we have previously observed, changed the sulphides into sulphates, oxides and carbonates.

The presence of a dyke near to or cutting a vein has been found often to enrich the latter at the point of contact.

In the "Colorado Central" mine at Georgetown a narrow dyke of brown obsidian traverses a larger dyke of ore-bearing porphyry. The valuable ore is found close to the obsidian dyke. This might be the result of greater heat at that point. The "black dyke" in the Comstock mine is a somewhat similar case.

PALEONTOLOGY OF ORE DEPOSITS.*

By finding certain characteristic fossils in the country rock enclosing the ore bodies, we determine its geological age. Thus in Colorado, in the Leadville region, we find occasionally in the ore-bearing "blue limestone" a shell something like a cockle-shell with straight shoulders and a broad groove down the middle of the shell; this is called a Spirifer (Spirifer Rocky-Montana). Another rather humped-backed, round-shouldered shell, the size of a walnut, with short spines sticking out from it, is called a Productus; and a third, of a spiral shape, not unlike a large snail shell, is called Euomphalus, and another snail-like shell Pleuroto-Maria. These shells being characteristic of and peculiar to the Lower Carboniferous in various parts of the world, label the geological horizon whose rocks carry the ore at Leadville as belonging to that period.

At Aspen, some seventy-five miles distant, the same fossils occur in a "blue limestone," together with a great number of fossil corals, some cup-shaped, and others full of pores like the section of a sugar-cane. The former

*See plates of fossils in Appendix.

belong to the "Zaphrentis" class of corals; the latter are called "Syringopora."

The similarity between the fossils in the ore-bearing blue limestone at Leadville and Aspen enables us to state that the ore deposits of both regions are in the same geological horizon and the ore bodies situated in very nearly the same belt and much the same circumstances.

The importance of this is obvious. Leadville having produced so wonderfully in the past, if it can be proved that the newer camp of Aspen has deposits in the same belt and similarly situated, it would be so much in Aspen's favor.

Too much reliance as to the future of any camp must not be grounded on these geological facts. Local circumstancee, besides those of merely being on the same geological horizon, may have much to do with the distribution of ore. Thus, while it would be wise to follow up this peculiar limestone, and prospect it wherever it appears between Leadville and Aspen, it by no means follows that it will everywhere prove productive of mineral. The most likely places for mineral deposit would be where it happens locally to be traversed by eruptive porphyries, or where there are signs of porphyries or eruptive rocks being in the vicinity of the limestone.

As limestones of different ages are often very similar to one another in color and composition, the finding of these peculiar fossils is very useful in distinguishing and tracing them over the country; but in Colorado these fossils are not so common as we might wish, and in lack of them a prospector might form a shrewd, but not very certain guess at the identity of this ore-bearing limestone by its position on a cliff section relative to other formations.

Generally speaking, this Lower Carboniferous limestone may be found four hundred to five hundred feet above the granite, the interval being occupied by a well-defined belt of white quartzite about 200 feet thick, and upon that a drab-yellow dolomitic limestone ("white limestone"*), also about 200 feet in thickness. Of course this thickness may vary much with localities. Then again, above the blue limestone usually comes a bed of black carbonaceous shales, then a thick bed of grits and sandstones, and then red sandstones. The blue limestone will lie then somewhere between the red sandstones and the granite. The long section, together with the vertical section, accompanying this report will show the general position of these strata.

A lack of ability to distinguish the age and position of certain limestones has led to a great deal of useless prospecting in Colorado. On the other hand, largely by means of these fossil shells, the Geological Survey has been able to follow the Leadville ore-bearing belt for many miles along the Mosquito range and over the range to the region around Mt. Lincoln, Breckenridge and South Park, and again further North up the Arkansas river to the Eagle river, to Redcliff, and thence to Aspen. Similar rocks, too, have been identified by means of their fossils, as far down as Tombstone, in Arizona, and Silver City, New Mexico.

To resume our section: Next below the blue limestone, with sometimes an intervening bed of white quartzite, called the "parting quartzite," comes a bed of 200 feet or more of drab-yellowish dolomitic limestone, full of white flints; it is locally called "white limestone." In this a few shells have been found sufficient to identify it

*Known also as "short lime" by Aspen miners.

as belonging to the Silurian. This limestone yields ore, but not generally so well as the "blue lime."

Below this is a bed of hard, white, crystalline quartzite, which has yielded very few obscure fossil impressions. The fossils appear to have been obliterated by the heat attending metamorphism. From its general position on top of and immediately upon the Archæan granite, and its position underneath the fossil-defined Silurian and Carboniferous above, it is considered to belong to the lowest division of the Silurian, called the Cambrian. This Cambrian quartzite has yielded gold in South Park and at Redcliff.

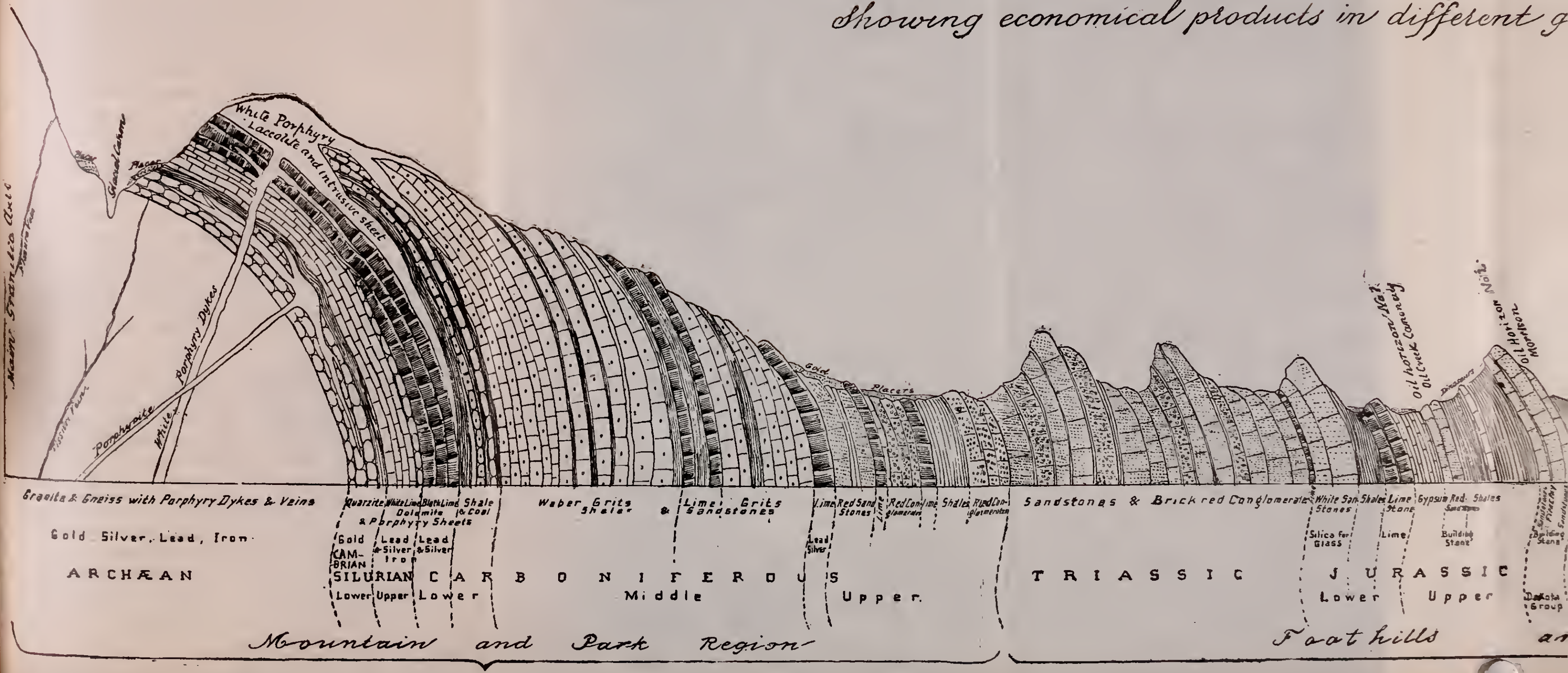
This brings us to the granite, in which there are no fossils, but it is not difficult to recognize it. It is the "bed rock" of the world, the Archæan or beginning, and here paleontology stops.

If we now begin again from the top of the Carboniferous limestone and ascend, we shall find dark shales, stained with coaly material, and even some small seams of anthracite coal, and among them (near Sheep Mountain, in South Park), actual impressions of the singular foliage of the Carboniferous epoch, such as gigantic horsetail rushes (equiseta), and tree-ferns similar to those found overlying the coal in Pennsylvania.

These fossils confirm our opinion as to the ore-bearing limestone being Lower Carboniferous, and that these grits and shales represent the Middle or Upper Carboniferous. The grits have not, so far, produced much ore. Above this thick-bed of grits, called "*Weber grits*" because they are developed on an enormous scale in the Weber cañon in Utah, we find a few beds of limestone, some shales and some coarse, dark-brownish red conglomerates.

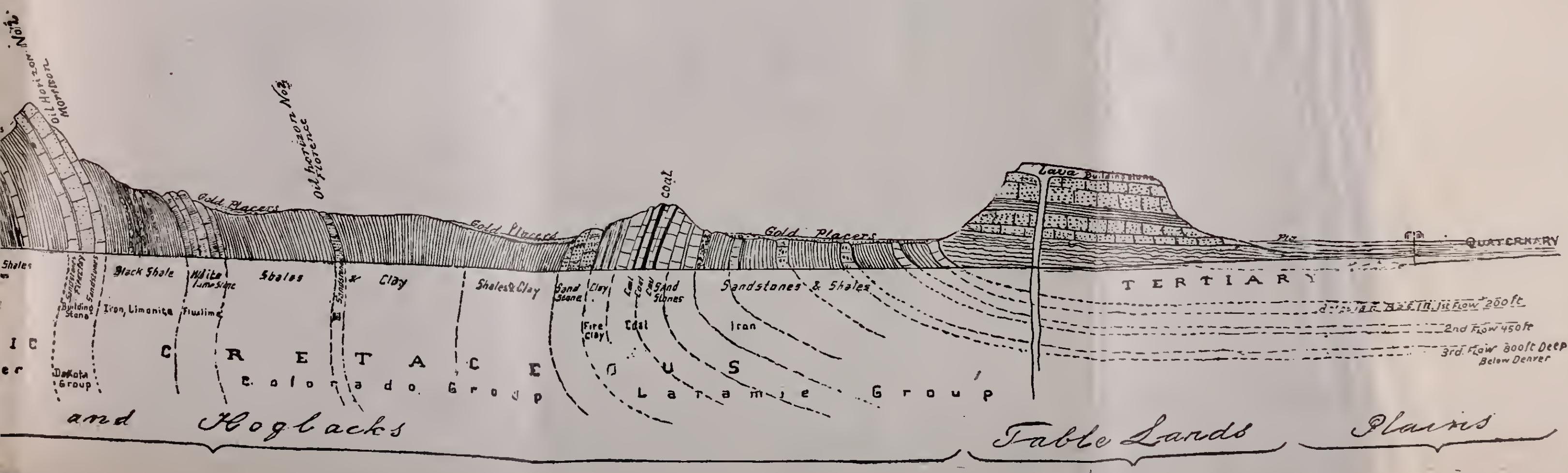
Generalized Section of Rocky M

Showing economical products in different g



...y Mountains in Colorado.

...ent geological horizons and strata



The limestone has yielded some fossil shells, showing it to be Upper Carboniferous, and at Kokomo, in Ten-Mile district, at the Robinson mine, large bodies of ore have been discovered associated with eruptive porphyries. This is, with the exception of the ore deposit in the Gunnison district, about the highest horizon in which ore bodies are found in place in Colorado.

[In the shales near Fairplay, South Park, the writer discovered some interesting remains of fossil insects and foliage, which have been determined as probably belonging to the Upper Carboniferous.]

Next follows a great thickness (from a thousand to two thousand feet) of coarse red conglomerate sandstones, supposed from their position relative to well determined Carboniferous beds below, and Jurassic beds above, to be the Triassic and to mark the beginning of the Mesozoic era in Colorado. No fossils have been found, however, to make this certain. A few copper stains is all the mineral found in this formation in this State.

Next above this are a series of variegated clays and shales, red, purple, green and gray, also a bed of thick white sandstone near the base which has been used for glass, being nearly pure silica. There is a bed of limestone in the middle which is burnt for lime among the foothills. In the shales and clays of the upper portion of this Jurassic formation the writer discovered some large skeletons of dinosaurs or "terrible land lizards" at Morrison on the foothills and also in Wyoming. These remarkable fossils show the formation to belong to the Jurassic. Some shells discovered in the limestone in Wyoming also prove the same thing. There are no important minerals in this group. Oil has been found in the "saurian beds" on Oil Creek, near Cañon City. Above this, along the foothills and in the basin of the parks, is the prominent sandstone "hogback" of the Dakota group, the floor of the Cretaceous epoch in Colorado, identified by peculiar leaf fossils found in it. In the center of this "hogback" is found a bed of fire clay of excellent quality.

The middle or Colorado group of the Cretaceous consists of dark and drab clays full of marine shells, some of them called Ammonites are often mistaken for fossil snakes coiled up. Another straight shell, called Baculite, often covered with mother of pearl, resembles an eel cut in two, and is often supposed to be a fossil fish. In the middle of this Colorado group, between one and two thousand feet below the coal beds, oil has been found in a loose sandstone at Florence, near Cañon City. There appears to be two horizons or two oil sands near Cañon City, one in the upper Jurassic, the other in the Colorado group of the Cretaceous, both may probably originate from strata of a still lower geological horizon.

Near the base of this Colorado group is a prominent bed of white limestone, much quarried for flux for the smelters, being a nearly pure carbonate of lime. In it are found large round shells about the size of a saucer, and not unlike a modern clam; these are called "inoceramus." This limestone near Schofield, on Rock Creek in the Gunnison, is traversed by argentiferous galena veins.

Next come the Laramie-Cretaceous coal beds, consisting of sandstones, clays and shales. The important coal seams lie in a thick bed of sandstones near the base of this group. Beds of inferior limonite iron ore are also found a short distance above the coal. The upper portions of this group for 1,000 feet have yielded, at intervals, very good artesian water, at Denver and elsewhere. Throughout the Laramie group abundant fossil remains of tropical foliage, such as palm leaves, fig leaves, cinnamon, etc., have been found to identify its horizon. The sandstones near the coal are quarried for building stone. The Tertiary which lies on the top of this, and unconformably with it, consists of pudding-stone, conglomerates, shales, thin seams of coal and plant remains. Its unconformity to the Laramie is among the leading characteristics that prove its Tertiary origin. It generally forms table lands, and is often capped by some form of more recent lava, the latter is quarried for building stone. Spread over all these formations alike, in mountain cañons and along river courses, we find the glacial moraines, cobble stones, sands and boulders, sometimes modified by water into stratified beds. These, as we have said, are our gold placer beds. Remains of the mammoth and mastodon have been found in these beds in Colorado, a sufficient evidence of their Glacial and Quaternary origin.

On top of this is the soil of the present age, in which we find bones of buffaloes and deer, and relics of civilized man and uncivilized Indians.

It will appear from the colored section to what a limited portion of this ten to twenty thousand feet of strata the bulk of our precious metals are restricted, viz: To the first few hundred feet of the lower and geologically older portion.

GEOLOGICAL AGE OF VEINS AND ORE DEPOSITS.

As veins are necessarily of more recent date than the rocks which contain them, we may, in a negative way, get approximately at their geological age of formation. For instance, if a series of veins penetrate the Archæan, they must have been formed during or after the Archæan. If penetrating the Carboniferous, as at Leadville, after the Carboniferous, and so forth.

But, though we can state with certainty that certain veins and ore deposits were formed *after* such and such an age, it is difficult to limit them to the exact interval of time in which they were formed. If, for example, we found a series of veins penetrating to the top of the Archæan granite and ending abruptly at the Silurian, we might suppose that they were formed at the close of the Archæan and before the deposition of the Silurian, but the evidence would be only negative, as there is nothing to show but that they may have been formed quite recently, and that the fissures only extended to the top of the Archæan without having force enough to break through into the Silurian. For instance, at Steamboat Springs, Nevada, veins are to-day being formed by hot water coming up through a fissure in the granite.

The ore deposits characteristic of Leadville are found in neighboring districts to extend as high as the base of the Triassic, or beginning of the Mesozoic era; therefore they must have been formed as late as the opening of the Mesozoic. We have proofs, however, that they were formed before the great upheaval movement at the close of the Cretaceous, because the deposits are folded and faulted by that movement.

Vein and ore deposits have been forming from a very early age up to the present time, and are still forming, as shown by the case of the Steamboat Springs we have alluded to.

These springs are situated on a line of fissures extending in the direction of the celebrated Comstock mine fissure. The springs emit steam from a series of parallel fissures, which are lined with successive coats of silica, assuming the banded structure observed in the veinstone of ordinary fissure veins. The fissure at one point has been opened beneath by a tunnel, and found to contain a quartz vein containing copper and iron pyrites, together with cinnabar and gold. Here we seem to have all the conditions of a fissure vein forming before our eyes.

The great Comstock mine fissure appears to have had much the same origin, and the extraordinary heat that is met with at a depth of 3,000 feet is probably the approach to the retreating and dying geyser. It is possible that some of the fissure veins in the San Juan region may have been formed by the action of now extinct hot springs and geysers, as the whole region shows evidence of great volcanic activity in past time.

ERUPTIVE LODES.

Metalliferous matter is sometimes disseminated through igneous eruptive rocks, as, for example, through the gold-bearing dykes of porphyry at Breckenridge.

Metals occur in such rocks in minute particles, or as quantities of various compounds of the heavy metal. In some cases these have been chemically dissolved out, and the metals again thrown down in such a way as to form valuable metalliferous deposits. In Australia, in South Park (Colorado), near Prescott (Arizona), and in various other places, such impregnated dykes have become decomposed. The originally disseminated gold has been deposited with quartz and other minerals, in the joints and fissures of the rock. In a certain sense these may be called eruptive lodes, and owe their origin indirectly to eruptive igneous agencies.

BRITANNIA MINING AND SMELTING CO. LIMITED

ORIGIN OF ORE DEPOSITS.

The questions are sometimes asked, "Where do the precious metals come from?" "What is their origin?" "How are the mineral veins formed, and how do the precious metals get in them?" The remote origin of minerals and metals is a matter of speculation. They may have formed part of that "world-mist" of gaseous matter from which, according to the nebular theory, our planetary system was evolved, and as the gaseous mist consolidated and passed into a molten condition, the precious metals may have separated and entered into various combinations, and have been arranged in the general make up of this globe according to their specific gravity. Hence it has been argued by some that the interior of the earth is more metalliferous than the surface crust, a theory which is somewhat supported by the fact that the specific gravity of rocks near the surface of the earth is less than that of the interior of the earth; in other words the earth grows heavier towards the center. Volcanic rocks, too, that come up from depths unknown, contain a large per cent. of the heavier metals, such as iron, and it may be that the more remote source of the precious metals we now find concentrated in veins, is from the deep interior of the earth. But let us leave this as a matter of speculation and confine ourselves to facts more within the reach of observation and to the more immediate source of the metals which for miners has a practical interest.

THEORY OF THEIR FIERY ORIGIN.

An old theory, now generally abandoned by geologists, but still prevailing amongst miners, is the "igneous theory," or the fiery origin of veins and metals. The fissures themselves are by some attributed to volcanic outbursts and the veinstone and metals in them to fiery, molten, volcanic emanations, coming up from below like lava, filling an open fissure, welling up as through the throat of a volcano. Others seem to demand even more intense heat than this, and imagine that the metals we find in the veins are the condensed vapors of metals in the bowels of the earth, reduced there by intense heat to a vaporous condition ascending through the fissures, and again condensing in a solid crystalline form in the upper and cooler portions of those fissures, somewhat as certain sublimed vapors from a smelting furnace collect and recrystallize in the flues.

To many miners and prospectors every indication or surface appearance of a vein is called a "blow out," a term suggestive of some sort of volcanic explosion at that particular point. And with many the "igneous theory," the "fire and brimstone" origin of veins is as deep seated as the veins themselves in the masses of the rocks. We may say here that though this theory may appear plausible in some points, yet in its extreme form it by no means accounts for the phenomena we find in the veins themselves, as will appear later on. It contains, however, a measure of truth, nor is it unnatural that this "igneous" origin should have suggested itself, when in Colorado, veins are so generally associated with volcanic rocks and evidences of volcanic action. Moreover, it is held by some that the ore deposits derive their materials directly from elements widely and minutely diffused through the volcanic rocks, and it is almost certain that the presence and heat of these rocks was indirectly a necessary condition to the formation of most of our veins and ore deposits.

SOURCE OF METALS NOT FAR OFF.

The advance of late years in the study of vein and ore deposits goes to show that we need not draw upon the unknown, profound, ignited regions of the earth's interior for the direct source of the metals as we find them in the rocks, nor to violent explosive or sudden volcanic energies, nor even to very intense heat, such as the igneous and sublimative theory requires, but we may look much nearer home for the immediate source of the metals we find in the veins, namely, in the elements of the common "country rocks" adjacent to the ore deposit or forming the walls of the fissure, and for the medium of their distribution and concentration need nothing more violent, explosive or volcanic, than water, which need not be intensely heated in all cases, nor intensely violent, but rather slowly oozing or percolating. Nor is it necessary that the filling of a vein with gangue and metal should all come from foreign depths below, or from below altogether, as the igneous theory demands, but quite as much from the sides of a fissure, or even in some cases from above the position occupied later by the ore. In a word, veins, whether fissure veins or blanket, or in whatever form they may occur, are not so much vents for volcanic action as simple courses for water, heated or not, carrying with it minerals and metals in solution and depositing them partly by cooling and partly by relief of pressure and partly in some cases by chemical action.

HOW THE VEIN FISSURES AND OPENINGS WERE FORMED.

As regards the openings and weak places in the earth accessible to mineral solutions and now found filled by vein stone or metalliferous matter, these are of various kinds and of various origins.

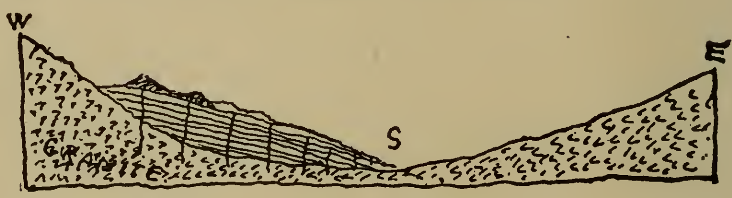
The fissures occupied by what are called "true fissure veins" in our mountains, such as those of Clear Creek county, are caused generally by the fracturing and slipping of rocks in the process of folding upwards or elevation of the mountain ranges, a process so very slow and gradual that it may be even going on at present without our noticing it. The relief of tension producing the faults and slips, though the fault fissures may extend to very great depths, was likewise probably not violent but gradual. From time to time the shock produced by the grinding together of the walls of the fissure in a slip of only a few inches, but extending down through thousands of feet of rock, may have given rise to earthquakes more or less violently felt upon the surface. Other openings occupied by fissure veins may have been caused by contraction and shrinkage of the granite rocks in consolidating from a soft semi-plastic condition to one more solid and compact.

The great "gash" fissures such as we find occupied by veins in the volcanic sheets of the San Juan, Creede and Cripple Creek regions, appear due, not to great earth movements like the last, so much as to openings formed by cooling and contraction of the lava, much as may be observed on the cooling of a slag furnace.

Ore deposits of lead and other minerals in limestone and other sedimentary rocks find their way through the vertical joints common to all water-formed rocks, due to the contraction of the rock in passing from a soft muddy condition to one more solid; the same may be seen on a small scale on the mud of a pond that is drying up. Such fissures are short, but they act as channels to a more important line of weakness, generally occupied by the main body of the "blanket" deposits of ore, viz: the porous dividing line between one set of strata and another, or between one stratum and another. Another line of weakness for the attack of mineral solutions is at the juncture of a porphyry sheet or a porphyry dike with some other rock, where we find our "contact veins." The heat of the volcanic matter may also have greatly influenced the solutions, even if the porphyry did not actually supply the metallic element in the vein.

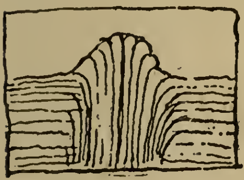
METALLIFEROUS FISSURE VEINS NOW FORMING.

To the researches of Le Conte, Emmons, Newberry and Sandberger we are mainly indebted for our recent knowledge of the origin of veins and ore deposits. According to Le Conte, at Steamboat Springs, Nevada, and at Sulphur-bank, California, we have fissure veins forming before our eyes, and revealing the process by which the old fissure veins were produced.



STEAMBOAT SPRINGS.

At Steamboat Springs clouds of steam issue from many vents over a bare rocky space, a half a mile long, in a narrow valley with volcanic ridges on either side. The vents are separate, but occur in parallel lines, showing they are connected by fissures. These fissures are filled with quartz, dissolved and deposited by hot alkaline waters. The fissures traverse a continuous crust of deposited quartz which is half a mile long by 300 yards wide and 30 feet deep. Some fissures are open, some partly filled with quartz, with water issuing from a narrow crevice in the middle. Some are wholly filled with the quartz, and have become true quartz, fissure veins. Some of the larger fissures are a half mile long, a foot wide, open and parallel, about twenty-five feet apart and descending downward to the bottom of the quartz crust thirty feet, and can be followed no further because they have deposited quartz in such abundance as to cover up their original vents in the underlying country rock. Water does not issue from all the fissures, but can be seen and heard eight or ten feet below, in violent agitation from steam and carbonic acid gas. The quartz filling these fissures in the hottest parts is gelatinous, in others spongy, and in others hard, or in layers of agate, chalcedony or sugar quartz. Everywhere there is the same distinct, banded or ribbon structure we often observe in fissure veins, resulting from successive layers of quartz being laid on the sides of the fissure by water solutions. The quartz in these fissures contains sulphides of iron, copper, mercury and even free gold. The metallic contents, as in old fissure veins, are in much less proportion than the quartz veinstone.



RIBBON STRUCTURE.

The country rock below this fissured crust is a volcanic rhyolite lava, like that at Creede and Cripple Creek, pierced at one point by a dyke of volcanic basalt. The hot springs and steam vents are probably the weakened manifestations of volcanic activity that occurred most violently when the basalt was erupted.

Sulphur Bank in Lake county, California, is composed of volcanic rock much decomposed by acid vapors, traversed by numerous fissures, emitting hot water, steam and carbonic acid gas. Sulphur has been thickly deposited. The hot water contains carbonic acid gas, carbonate of sodium and ammonium; salt and borax. The sulphur contains cinnabar and the sides of the fissures in the volcanic rocks are coated with gelatinous quartz with layers of hard chalcedonic quartz behind them. In these newly forming fissure veins are found both pyrite and cinnabar. At Sulphur Bank volcanic andesite lava, like some at Creede, overlies Cretaceous sandstone and shales which dip at a steep angle.

CROSS-CUTTING A FORMING FISSURE VEIN.

These stratified beds have been opened up to a depth of 260 feet below the lava cap by a shaft, from which levels have been run towards the springs and fissures to cut the vein and ore body. For seventy feet from the shaft along the tunnel the rock is a barren sandstone, dry and cool, then it becomes "brecciated" or broken up into angular fragments, charged with ascending hot water 160° F, containing alkaline sulphides, carbonic acid gas and sulphuretted hydrogen. The heat of the freshly cut rock is intense. In this hot, shattered, brecciated rock is the ore. The brecciated layer forming the waterway is composed of fragments of sandstone and shale with their edges worn or dissolved away. These are cemented together with mud, but where the rock is drier the mud cement is hard and contains metallic sulphides. So the vein is a breccia of rocky fragments cemented together by a paste of cinnabar, pyrite and quartz. The fragments of rock are coated with alternate layers of these metals, reminding one much of the peculiar metal coated boulders in the celebrated Bassick mine of Silver Cliff, Colorado, whose origin and history is probably very similar. The quartz is, in all stages, cheesy, gelatinous and hard. The vein matter is mainly in the open, loose brecciated layer, but is not confined to it and is quite irregular, widening and thinning; and sometimes disappearing, much as in our Clear Creek veins.

In these newly forming fissure veins we seem to see the process by which our ancient fissure viens were formed. It is to be observed that at Steamboat Springs the hot waters are mainly alkaline carbonate in character, and so dissolve, bring up and deposit more quartz veinstone than metals, whilst at Sulphur Bank the waters are more alkaline sulphide, and so carry into the vein more metallic sulphides. This perhaps accounts for many of our fissure veins being filled only with barren quartz, whilst others abound in metals, depending upon the different chemical character of the waters circulating in the different fissures.

It is significant that the great Comstock fissure vein, one of the most typical and productive fissure veins in the world, is in the same region and but seven miles from Steamboat Springs. Its origin and natural history seem identical with the Steamboat and Sulphur Bank veins. The Comstock fissure occurs in volcanic, lava rocks, filled with quartz and metal. At a depth of 3,000 feet the water of the vein increased in volume and heat, the latter to an unbearable intensity of 157° F. It is evident that the Comstock shaft is pursuing downwards a retreating hot spring, which at an early period deposited the quartz and metal found filling the upper portions of the fissure, by relief of pressure and cooling, from materials doubtless derived from the elements of the adjacent volcanic rocks.

We may conclude then that fissure veins have been filled by hot alkaline solutions, dissolving and depositing both quartz veinstone and metallic sulphides derived from the surrounding rocks, leached from them at various depths.

METALS DEPOSITED FROM SOLUTIONS.

Some minerals and metals found in veins may appear to the chemist from his laboratory experiments as too insoluble to have thus been deposited by solution, but we must not compare the brief experiments in our little laboratories with the great laboratory of nature, with her vast resources of heat and pressure, and subtle chemistry, and the infinite slowness and patience of her work. Solubility is much increased by heat and pressure, and in volcanic regions there is abundance of both for the waters, which consequently dissolve mineral and metal matter wherever they find it in their underground course. Then add to this alkaline carbonates and alkaline sulphides present in the water to dissolve quartz for veinstone and metallic sulphides for ore, and thus both gangue and metal are mingled in the same solution. The material both for gangue and metal may be derived by leaching of the country wall rock all the way down the fissure to its lowest depth, and especially in those lower depths, because there the heat and pressure are greatest and the waters in consequence more actively solvent. So contributions may come into the fissure both from ascending waters and those oozing in from the sides, draining a large underground area of rocks containing metalliferous matter, minutely and widely diffused, and carrying these in solution into the relief channels of the fissures, and there depositing them in a concentrated form as explained. Hence it is that great fissure veins have such a variety of minerals in them because they draw materials from such a large and varied area of rocks. In most cases it would appear from the association of these veins with volcanic or crystalline rocks in Colorado, as if the solutions were generally hot, but some metals may be deposited without heat, as for instance bog iron ore and lead. The latter in Missouri occupies shrinkage cracks and cavities in limestone where there is no evidence of great heat.

Gold, though so insoluble, has doubtless also been deposited by solution, for we find it intimately wrapped up in iron pyrites. Gold is soluble in persalts of iron and alkaline sulphide, so we may suppose that gold veins were formed like the rest, by hot, alkaline carbonate and sulphide solutions, the gold and the sulphide crystallizing together.

Subterranean waters deposit along their waterways in various manners. Deep fissures occupied by fissure veins are the main highways of upcoming waters, decomposing the walls of the fissure, and forming a clay "gouge" and depositing quartz and metal. But crust movements may only shatter the earth and produce short "gash" veins, or still further shatter it into broken blocks, and give us a brecciated vein, cemented with ore and quartz, as at the Bassick and some of the San Juan mines. Or the waters may act chemically on a soluble limestone and deposit chemically by substitution, as at Leadville, or saturate a porous sandstone, as at Silver Reef, Utah, but the process though varied is in the main the same.

COUNTRY ROCK THE SOURCE OF ORE.

Sandberger has thrown much light on the probable immediate source of metals found in veins, by showing that the heavy, basic and usually dark minerals, such as mica, hornblende and augite, which are among the constituents of granite, porphyry and volcanic rocks, contain in minute parts the elements of nearly all the precious metals known, and so in the chemistry of nature the waters may draw from the elements of the country rock all the metal found in veins, without having recourse to a deeper and unknown mysterious source. Emmons has proved the same theory for the ore deposits of Leadville. He has found in the minerals composing the great eruptive sheets of porphyry which overlie the ore deposits and ore-bearing limestones of Leadville, sufficient elementary metals to account for all the ore at present found in the Leadville deposits, with a good deal to spare. And as the limestones by themselves contain in their elements no such metallic substances, he attributes the great ore deposits found in them, to waters passing through the porous porphyry sheets, leaching out their metallic elements and depositing them at the "contact line" between these two rocks, as well as in the jointage channels of the limestone.

THEORIES OF VEIN ORIGIN.

From the numerous theories that have been put forward to account for the origin of veins and ore deposits, we select such as seem to us most in accordance with the facts of this difficult problem.

SUBLIMATION THEORY.

Vein fissures are supposed by this theory to be filled by the volatilization of metalliferous minerals derived from the ignited interior of the globe or from intense heat. This accounts for the unequal distribution of the ores in lodes by currents of dissimilar gases or vapors circulating through fissures in the veinstone. These dissimilar vapors meeting, combine and precipitate various metals. Magnetite and specular iron are thus produced by decomposition of chlorides of iron, by watery vapors in fissures of modern volcanic rocks. Magnetite and galena have also so been formed by sublimation in the flues of smelting furnaces, and also tin oxide, zinc-blende, pyrites and other vein minerals.

This theory, though it may contain some truth, does not account for earthy minerals forming veinstone in veins, nor various other phenomena connected with veins.

Cinnabar, iron pyrites and gold are now, as we have said, being deposited from the waters of the geysers in Nevada. Quartz with its large crystals appears to be deposited by water only.

LATERAL-SECRETION THEORY.

This is one of the most important theories of modern days, and is principally due to the labors of Prof. Sandberger. "Water percolating through the country rock has by aid of carbonic acid and other solvents, dissolved out of it all the materials now forming the constituents of veins.

Some lodes in this connection, show a marked difference as they pass from one variety of "country rock" to another. Sandberger's examination has proved this to be due to metals being derived from those rocks, and further that the metals were derived more particularly from certain constituent minerals of those rocks, such as mica, hornblende, augite and feldspar, the common constituents of such rocks as granite, the porphyries, and other eruptive crystalline rocks.

In each of these common minerals the elements of the metals occurring in metalliferous veins were detected and proof found that the heavy metals exist in the silicates of crystalline rocks of every geological age.

In olivine (a common crystal of basalt), iron, nickel, cobalt and copper were found.

In augite another constituent crystal of the same and other igneous rocks, lead, tin and zinc were found.

Hornblende, common in granites and eruptive rocks, contains copper, arsenic, cobalt, lead, nickel, antimony, tin, zinc and bismuth.

White micas yield tin, arsenic, copper and bismuth.

Black micas are not so productive, but yield similar metals.

The feldspars, especially certain varieties of them, yield baryta and lime for veinstone, while their liberated silica yields the quartz.

Thus, in these little minerals so common in nearly all rocks, especially those associated with our ore deposits directly or indirectly, we have all the elements necessary for the metals and the veinstone of veins and ore deposits, near at hand in the adjacent rock, without having recourse to the deep ignited regions of the earth, as required by the "igneous" and "sublimation" theories of the origin of veins.

"Organic matter is sometimes present in veins in the form of graphite and anthracite, it also forms the coloring matter of smoky quartz, fluorspar, etc. This occurs when the amount of organic material originally present has been more than sufficient to transform the metallic sulphates into sulphides."

In the depths and near the surface of the Bassick mine at Silver Cliff, Colorado, a substance resembling charcoal is found.

As lodes occur both in crystalline and semi-crystalline rocks, and also in rocks derived from these, such as sandstones, ores may be derived from the incompletely decomposed remains of metalliferous silicates such as mica, hornblende, etc., from the original crystalline rocks such as granite, or from solution products from older veins, or from traces of metals which are found in sea water.

Copper and gold have been detected in the waters of the Mediterranean.

In gypseous deposits of ancient seas copper is sometimes present.

In the red Trias sandstones of South Park, which were doubtless deposited in inland seas or estuarine formations, copper stains are common. Copper is similarly found in modern estuarine muds. Stratified rocks such as sandstones, that have been formed by the sea, consist of the *debris* of older crystalline rocks such as granite, which contain, as we have said, both the elements of the heavy metals in their constituent minerals and also in veins in their mass, hence it is not surprising that we find copper stains in the Trias conglomerate, and at Morrison we have even found large crystals of galena in the boulders composing the conglomerate. Copper and zinc again have been detected in clay slates of marine origin.

Some strata possess a composition enabling them to decompose metalliferous solutions derived from other sources more readily than others, and re-deposit their contents in the form of ore. Limestone, for example, not in itself a metalliferous rock, seems a favorite receptacle of ores or ore solution from other richer or ore-generating rocks.

ASCENSION THEORY.

According to this theory lodes were formed in part only of minerals dissolved out of the adjacent country rock. The chief portion of the material was derived from greater depth by solvents circulating through the fissures, sublimation assisting either with or without steam. The increased heat and pressure due to greater depth enables the solution of different vein-forming substances and minerals to be deposited in all parts of the fissure of which the constituents do not exist in the rocks or the immediate vicinity.

The solutions will, under great pressure, penetrate deeply into the surrounding rocks, and impregnate them with metalliferous minerals, also softening and decomposing the rocks to a considerable distance from the lode, or they may silicify the cheeks of thc fissure.

"Waters of solvent powers, increased by high temperature and pressure, percolating through rocks containing heavy metals will gradually remove them by lixiviation, together with other mineral substances. These will again be deposited upon the sides of the fissure in proportion as the solvent powers of the mixture become lessened by diminishing temperature and pressure."

Minerals diffused through rocks near the surface may be removed by solutions which, penetrating into vein fissures, have mingled with the waters circulating through them. Deposits akin to those of true veins are at present being formed by the action of hot mineral springs, as in the Steamboat Springs of Nevada.

Sulphur is also found in these deposits and occurs in the old auriferous reefs of Australia and in some of the mines of Redcliff. Sulphuretted hydrogen may account for the formation of certain metallic sulphides in veins.

ORIGIN OF LEADVILLE ORE DEPOSITS.

The Leadville ore deposits have been the most thoroughly investigated by the U. S. Geological Survey under Mr. S. F. Emmons, of any of the mineral deposits of Colorado, and as the results of the investigation have a bearing upon many similar occurrences of minerals in the Rocky Mountains, we give an epitome of his views.

"The ores are deposited for the most part in the 'blue limestone' of the Lower Carboniferous. As the ores were deposited by water solutions, the soluble limestone beds would be more easily acted upon by solutions than the sandstones and shales composing the other rocks of the neighborhood which are less susceptible to percolating water. The Paleozoic formations in America are the principal repositories for lead and silver ores, not by reason of their geological age, so much as by their containing such a quantity of soluble limestones, and being physically as well as chemically favorable for the reception of mineral solutions.

"The physical, structural conditions of Leadville are particularly favorable to the concentration of percolating waters in the blue limestone. Great intrusive sheets of porphyry follow the limestone persistently, principally on its upper surface. This porphyry is very porous, and full of cracks and joints, affording ready channels for water from above, and also channels for ascending water from below along the walls of the fissures, through which it is erupted. Such waters passing through a medium of different composition would be ready for a chemical interchange with the limestone."

COMPOSITION OF ORES.

The ores were deposited originally as sulphides. This is shown by the fact that the oxidized ores near the surface pass down with depth into sulphides. In Ten-Mile district these oxidized ores are seen to result from the alteration of a mixture of galena, pyrite, and zincblende. There is very little gold in the average Leadville ores; what little there is comes mainly from the Florence mine (native gold), and from others where it is associated with pyrites. It is usually associated with porphyry rocks, and a porphyry commonly called pyritiferous porphyry shows gold to exist diffused through the pyrites disseminated through its mass.

Silver occurs as chloride, a secondary condition, its original condition probably being sulphide.

Lead occurs as carbonate and sulphate, and deep in the mines as sulphide. Specimens are common of galena nodules surrounded by a thin coat of sulphate, and that again by a coat of carbonate, showing the order of transition from sulphide to sulphate and thence to carbonate.

In the Iron mine native sulphur occurs as an alteration product of galena.

Iron and *manganese* constitute rather a gangue material than an ore. They are hydrated oxides and protoxides. The iron was originally deposited as sulphide or pyrites, but has been wholly transformed by oxidation.

Zinc is not common, but occurs as calamine (zinc silicate) in needle like hairs and white crystals in cavities in the mines. Its original form was zinc-blende (zinc sulphide), as shown in the Ten-Mile district.

The earthy materials, alumina, lime, silica and magnesia, are in fair proportions, as might be expected from ores which are a replacement of limestone in close connection with porphyry. The alkaline element among the ores might also be traced to the influence of the latter rock.

The agents of alteration were surface waters, which contain everywhere carbonic acid, oxygen, organic matter, chloride of sodium (common salt), and phosphoric acid. The rocks through which these waters passed, such as porphyries and limestones, were found to contain phosphoric acid and chlorine, while organic matter exists in the blue limestones, and in the overlying shales and sandstones are many carbonaceous beds and even beds of coal. Water passing through these rocks would take up all these elements and be ready for chemical reactions.

Galena (lead sulphide) is much richer in silver than its alteration product, carbonate of lead, or cerussite. On Carbonate Hill the carbonate averages 40 oz. silver, the galena is 145 oz. to the ton. But galena is harder of treatment.

Silver is found at times disseminated through vein matter and country rock, without the presence of lead, proving that during alteration silver was removed farther from its original condition and more widely disseminated than lead.

Outcrop deposits have proved in many cases richer than those at depth. The deposits near the surface have been the refined, concentrated remains of larger bodies gradually removed by erosion as the alteration by surface waters went on. The baser and more soluble metals have thus been removed in solutions, leaving behind the more valuable and perhaps less soluble metals in new and richer secondary combinations.

Kaolin or *Chinese talc*, which occurs both along the line of contact and between the porphyry and limestone and also in the heart of the vein material, is a decomposition product from porphyry. It consists principally of hydrated silicate of alumina, doubtless derived from the feldspar of the porphyry, perhaps at the time when acted upon by sulphurous waters which brought in the *original* ore deposits.

Calcite occurs incrusting recent crevices and lining recent cavities, but in small amount.

Barite or heavy spar is common, generally associated with chloride of silver and with manganese, and is locally recognized as a sign of rich ore.

ORE DEPOSITS AS SULPHIDES.

We have already stated that depth in the mines away from the surface waters proves this to have been the original character of the deposits.

Under what reaction could this occur?

Sulphides of the heavy metals may be precipitated from various solutions.

1st. Where they exist as sulphides, by sulphides of the alkalies and alkaline earths.

2nd. Where they exist as carbonates and sulphates coming in contact with solutions containing alkalies and sulphuretted hydrogen.

3rd. Where they exist as sulphates, which in contact with organic matter are reduced to sulphides.

Metallic sulphides are soluble in water containing alkalies or sulphuretted hydrogen or silica, and in waters containing alkaline carbonates.

Solfataric or hot waters, arising from the heated depths, contain sulphuretted hydrogen, alkaline sulphides, and carbonates.

If the metals of these deposits came up from the heated depths or were derived from pyrites and galena in neighboring rocks, then the iron and lead were brought in as sulphides. This would seem to involve that the carbonates and sulphates of the limestone should have been dissolved out and carried away before the sulphides were deposited, and this would involve the popular "pre-existing cavity" theory (which Mr. Emmons believes to be incorrect). Probably, however, the dissolving out of the former so immediately preceded the deposition of the latter, that the process was an interchange of substance, for substance, or the commencement of a change from sulphide to sulphate may have taken place in presence of the carbonate, and the sulphate been immediately reduced to sulphide again by organic matter, and there is evidence that locally the dolomite limestone has been directly replaced by sulphides, by zincblende, pyrite and galena in pseudomorphs after calcspar and dolomite.

In contact with dolomite containing organic matter the sulphates would be reduced to sulphide with the formation of carbonic acid. The waters thus charged with carbonic acid would dissolve and remove the carbonates of lime and magnesia, which would be replaced by metallic sulphides.

Any excess of sulphuric acid would form soluble sulphates of lime and magnesia, which would also be carried away. If these sulphates were reduced to sulphides they would render the waters more capable of dissolving out the dolomite. The metals might have been taken up in the form of sulphates by waters percolating through rocks, where they might have been brought into combination by the oxidation of sulphides, or by decomposition of silicates, or in this transition the sulphates may have been reduced to sulphides by contact with organic matter before reaching the locality of deposit.

Sulphide of barium would be precipitated as sulphate of baryta in contact with limestones.

Silica brought in by waters containing alkaline carbonates, is soluble, and might form silicates of the alkalies, carbonic acid waters carrying away earthy carbonates.

Later, the combined alkalies were replaced by oxide of iron, and in part dissolved out, leaving free silica.

MODE OF FORMATION.

The Leadville ores, like most others, were deposited from water solutions by a metasomatic interchange, *i. e.*, substance exchanged for substance with the limestone, and lastly or originally, as sulphides.

Mineral matter is carried from one place to another within the earth's crust by heat and water, or these combined. Metasomatic interchange of metal for limestone and the removal of dolomite could only have been produced by water. The ores were *not* deposited in *pre-existing cavities*, but are a replacement of the country rock, *i. e.*, dolomitic limestone.

The ores grade off gradually into the material of the limestone, without a definite limit, as would have been the case if the limestone had been previously caverned. The only limiting outline to the ore bodies is that formed by the contact porphyry.

Fragments of unaltered limestone are found entirely enclosed within the ore bodies, and ore bodies often occupy the entire space for long distances between two horizontal sheets of porphyry, which space further on is occupied by the limestone. (This is well seen in the Colonel Sellers mine.) Examination of ores and veinstone show lime and magnesia not in the crystalline condition they would have, had they been brought into a "pre-existing cavity" and deposited, but in the same granular condition in which they exist in the country rock."

"The deposits in rocks other than limestone consist of metallic minerals and of altered portions of the country rock, in which the structure of the latter can sometimes be still traced, and are not the regular layers of matter foreign to the country rock, which results from the filling of a pre-existing fissure or cavity by materials brought in from a distance and deposited along the walls.

In the Ten-Mile district the arrangement of the particles of the original rock is frequently seen to be preserved in the metallic minerals which maintain a certain parallelism with the original bedding planes in the lines defined by minute changes in these minerals.

The common character of caves which have been dissolved out of limestone, is that their walls are coated with a layer of clay which has been left undissolved by the percolating waters, and these walls have a peculiar surface of little cup-shaped irregularities from which also stalactites frequently hang. There is also an accumulation at the bottom of the cave of fragments of limestone fallen from the sides of the roof. None of these characteristics are found associated with the ore re-placements.

Also, when mineral matter is deposited in "preexisting cavities" it takes the form of regular layers parallel with the walls of the cavity, as is beautifully shown in geodes lined with a succession of zeolites or with layers of chalcedony, opal, and quartz.

No such successive arrangement in layers is found in the Leadville ore bodies.

Again, could such large, open cavities have existed for long distances without support, between the layers of porphyry? Why did not these porphyry sheets close together? And further, how could such extensive cavities have been formed and kept open under a pressure of 10,000 feet of rock, which the geology of the region shows to have existed above the deposits, at the time they were being formed? Such cavities as we do find in the region are all of very recent origin, cutting through both limestone and ore bodies, and have been hollowed out by surface waters more recent even than those which produced the secondary alterations in the ore bodies."

ORIGIN OF METALLIC MINERALS.

"Ore deposits have been deposited from solutions through the agency of water, with or without the assistance of heat.

Within the rocks forming the crust of the earth there is a constant circulation of waters, carrying more or less mineral matter in solution, and no rock is absolutely impermeable.

There are upward and downward currents.. The latter are surface waters sinking by gravity. The former are the same waters rising under the influence of the heat of the earth. The direction which such waters take will depend upon the structure of the rock mass through which they pass, whether upward, downward or laterally.

Waters filling capillary passages and minute fissures will seek larger channels in joint, fault, and stratification planes. Water carrying mineral matter in solution along such channels will deposit it where the rock favors chemical precipitation or interchange, and this will take place most where there is some interruption in the flow, as rapid waters deposit less readily than those whose movement is slow."

SOURCE OF METALS.

"The ultimate source is a matter of speculation, like the nebular hypothesis, by which the earth is supposed to have arrived at its present condition as the result from the gradual cooling of an incandescent mass, and as the specific gravity of the crust is much less than that of the whole mass of the earth, it has been inferred that the heavy metals must be in much larger proportion in the interior of the earth than in the rocky crust," (though this greater specific gravity might be also accounted for by the rocks of the interior being much more tightly packed by pressure than those near the surface).

"Volcanic emanations and hot springs contain metallic minerals, so also do the waters of the ocean. But we know not from what depth the former came, nor from what source the latter derived them. As circulating waters take up and throw down their metallic contents under varying conditions, the same material may have been deposited more than once and in more than one form, since it reached the rocky crust. The ores do not seem to have ascended from below, for the geology of Leadville shows that the ores were deposited beneath a thickness of not less than 10,000 feet of strata and an unknown depth of sea-water. If they had been deposited from hot ascending solutions as the result of a relief of pressure, which would favor precipitation, the deposit would be found in the upper part of this mass of rock rather than at its base.

The sedimentary beds at the time of deposit were horizontal and undisturbed. There are no channels discovered through which the ore could have ascended, the eruptive rocks being horizontal and parallel with the stratification, hence the ore deposits were not formed by ascending waters.

The principal water channel at the time of deposition was the contact of the upper layers of the blue limestone with an overlying sheet of porphyry, and from this surface they penetrated downward into the mass of limestone. The currents were descending by gravity rather than ascending by heat.

Percolating waters circulate freely through eruptive rocks owing to their porous character, and their tendency to jointage and fracture, the results of cooling and weathering.

In sedimentary rocks the bedding planes are the natural courses for water.

Water would thus descend through the vertical joints of the overlying porphyry, and would turn off horizontally on or between the bedding planes of the underlying limestone into which they would eat their way gradually downwards, through jointage cracks and other weak points.

According to the "lateral secretion" theory, which seems nearest to the truth, all the substances contained in the lodes have been derived from the adjoining rocks. Sandberger and others have satisfactorily shown this to be the case, and that all metals found in veins can also be found in minute quantities in the constituent minerals such as mica, hornblende, augite, and other silicates of the adjacent or country rock. And, rather singularly, he considers the metals are derived more from these silicates than from the pyrite so commonly diffused through eruptive rocks, considering, moreover, that the latter are not original constituents of these rocks.

The results of a minute analysis of the rocks adjacent to the ore bodies at Leadville, viz.: porphyry and limestone, selecting fragments the most remote from ore currents and the purest obtainable, show baryta and lead to be contained in the feldspars of the porphyry. Gold and silver also exist in minute quantities in the elements of the porphyry, especially of that variety called pyritiferous porphyry, and those porphyries and diorites which contained the greatest amount of basic elements as a rule yielded the greater proportion of the heavy metals. The percentage of these metals is very small apparently, but when we consider the enormous amount of the porphyries (some even 1,000 feet thick,) actually present, not to mention those that have been removed by erosion, we see that this small percentage, if concentrated, would adequately account for all the metal found in the Leadville region, with a good deal yet to spare, minutely disseminated or chemically combined with certain earthy minerals constituting the elements of the great bodies of porphyry.

On the other hand the dolomitic limestone and other sedimentary rocks were found in themselves to show no original heavy metal elements.

The metals, then, came from the porphyry and were deposited only in the limestone. Some of them, too, may have ascended through the dykes that were feeders to the great horizontal porphyry sheets.

NEWBERRY'S THEORIES OF VEIN FORMATION AND ORE DEPOSITS.

Dr. J. S. Newberry, of Columbia School of Mines, groups mineral veins in three categories: 1. Gash veins. 2. Segregated veins. 3. Fissure veins.

Gash Veins.—"Ore deposits confined to a single bed or formation of *limestone*, of which the joints, and sometimes planes of bedding, enlarged by the solvent power of atmospheric water, carrying carbonic acid, and forming crevices, galleries, or caves, are lined or filled with ore leached from the surrounding rock; *e. g.*, the lead deposits of the Upper Mississippi and Missouri.

Segregated Veins.—"Sheets of quartzose matter, chiefly lenticular, and conforming to the bedding of the enclosing rocks, but sometimes filling irregular fractures across such bedding; found only in metamorphic rocks, limited in extent laterally and vertically, and consisting of material indigenous to the strata in which they occur, separated in the process of metamorphism; *e. g.*, quartz ledges carrying gold, copper, iron pyrites, etc., in the Alleghanies, New England, Canada, etc.

Fissure Veins.—"Sheets of metalliferous matter filling fissures, caused by subterranean force, usually in the planes of faults, and formed by the deposit of various minerals *brought from a lower level* by water, which, under pressure, and at a *high temperature*, having great solvent power, had become loaded with matters leached from different rocks, and deposited them in the channels of escape as the pressure and temperature were reduced.

Bedded Veins.—"Are zones or layers of sedimentary rock, to the bedding of which they are comformable; impregnated with ore *derived from a foreign source*, and formed long subsequent to the deposition of the containing formation." Several of the mines of Utah are cited, which are all zones in quartzite, which have been traversed by mineral solutions that have, by substitution, converted such layers into ore deposits of considerable magnitude and value.

"The ore contained in these bedded veins exhibits some variety of composition, but where unaffected by atmospheric action, consists of argentiferous galena, iron pyrites carrying gold, or the sulphides of zinc and copper, containing silver or gold or both. The lead carbonate and galena are often stained with copper carbonates. In the 'Green-eyed Monster' mine of Utah, the ore, thoroughly oxidized as far as penetrated, forms a sheet from twenty to forty feet thick, consisting of rusty, sandy or talcose soft material, carrying from twenty to thirty dollars to the ton in gold and silver.

"The quartzites are of Silurian age, but were impregnated by metalliferous solutions much later, probably in the Tertiary, and after the period of disturbance in which they were elevated and metamorphosed. This is proven by the fact that in places where the rock has been shattered, strings of ore run off from the main body, cross the bedding and fill interstices between the fragments, forming a coarse 'stock-work.'

"Bedded veins may be distinguished from fissure veins by the absence of all traces of a fissure, the want of a banded structure, slickensides, gouge, etc.; from 'gash veins' and the 'floors of ore' which accompany them, as well as from segregated veins, they are distinguished by the nature of the enclosing rock and the *foreign origin* of the ore.

"Sometimes the plane of juncture between the two contiguous sheets of rock has been the channel through which has flowed a metalliferous solution, and the zone where the ore has replaced by substitution portions of one or both strata. These are often called *blanket veins* in the West, but belong rather to the class of 'contact deposits.'

"Where such sheets of ore occupy, by preference, the planes of contact between adjacent strata, but sometimes desert such planes and show slickensided walls and banded structure, like the great veins of Bingham, Utah, these should be classed as true fissure veins."

THEORIES OF ORE DEPOSIT.

Doctor Newberry, as an advocate of the ascension theory, differs from Mr. S. F. Emmons and Mr. Becker, who lean toward the *lateral secretion* theory, and who, in their examination respectively of the Leadville and Comstock ore deposits, attribute the ores to the leaching of adjacent *igneous rocks*. He differs with them for the following reasons:

"First—The great diversity of character exhibited by different sets of fissure veins which cut the same country rock seems incompatible with any theory of lateral secretion.

"These distinct systems are of different ages, of diversified composition, and have drawn their supply of material from different sources. For examples, the Humboldt, the Bassick and Bull Domingo, near Rosita and Silver Cliff, Colorado. These are veins contained in the same sheet of eruptive rock, but the ores are as different as possible. The Humboldt is a narrow fissure, carrying a thin ore streak of high grade, consisting of sulphides of silver, antimony, arsenic and copper. The Bassick is a great conglomerate vein, containing tellurides of silver and gold, argentiferous galena, blende and yellow copper pyrites. The Bull Domingo is also a great fissure, filled with rubbish, containing ore chimneys of galena, with tufts of wire silver." Many other groups of mines are also cited, showing that the same rocks are cut by veins of different ages, having different bearings and containing different ores and veinstones. "It seems impossible that all these diversified materials should have been derived from the same source, and the only explanation is *the ascent of metalliferous solutions from different and deep-seated sources.*

"These and all similar veins have certainly been filled with material *brought from a distance* and *not derived from the walls.*"

LEACHING OF IGNEOUS ROCKS.

Against the theory that mineral veins have been produced by the leaching of superficial *igneous* rocks, he says:

"Thousands of mineral veins the world over occur in regions remote from eruptive rocks," and cites a number of examples. "In the great mineral belt of the Far West, where volcanic emanations are so abundant, and where they have certainly played an important part in the formation of ore deposits, the great majority of veins are not in *immediate* contact with trap rocks, and they could not, therefore, have furnished the ores." He cites several examples, and amongst them "the gold mines of Black Hawk, Colorado, the Montezuma, Georgetown and other silver mines in the granite belt of Colorado." In nearly all the localities cited he finds evidence not only that the ore deposits have not been derived from the leaching of *igneous* rocks, but also that they have not come from those of any kind which form the walls of the veins.

"The gold-bearing quartz veins of Deadwood, (Black Hills) Dakota, are so closely associated with dikes of porphyry that they have been considered as illustrations of the potency of trap dikes in producing concentration of metals. But we have evidence that the gold was there in Archæan times, while the igneous rocks are all of modern, probably of Tertiary date. This is shown in 'the cement mines' of the Potsdam Silurian sandstone. This is the beach of the lower Silurian sea when it washed the shores of an Archæan island, now the Black Hills. The waves that produced this beach beat against cliffs of granite and slate, containing quartz veins carrying gold. Fragments of this auriferous quartz and the gold beaten out of them and concentrated by the waves, were in places buried in the sand beach in such quantity as to form deposits, from which a large amount of gold is now being taken. Without this demonstration of the origin and antiquity of the gold it might very well have been supposed to be derived from the eruptive rock."

Again he says: "That where igneous rocks are most prevalent such districts are proverbially barren of precious metals, and where these metals do occur in such districts the same sheet of rock may contain several systems of veins with different ores and gangues." He cites the great lava plains of Snake River, of Eastern Oregon, Northern California and New Mexico as unproductive generally of ore deposits. Also the great lava plateaus of the Cascade range. On the other hand the Sierra Nevada, composed principally of *metamorphic* rocks, contains vast quantities of gold, silver and copper.

"At Lake City, in the San Juan district of Colorado, the prevailing porphyry holds the veins of the 'Ute' and 'Ulay' and 'Ocean Wave' mines, which are similar, whilst the 'Hotchkiss' and 'Belle' are entirely different. We have no evidence that any volcanic eruption has drawn its material from zones or magmas especially rich in metals or their ores. And on the contrary volcanic districts like those mentioned, and regions such as the Sandwich Islands, where the greatest eruptions have taken place, are poorest in metalliferous deposits."

He remarks that igneous rocks in our Western territories are "but fused conditions of sediments forming the underlying structure of that country." [They may be fused Archæan grantic rocks, but certainly not the higher series of Silurian, Carboniferous and Paleozoic rocks, for the simple reason that at Leadville and in our western region we can readily trace the vents or dykes from which this eruptive rock came up, penetrating deep into and lost in unknown depths of the granite, and thence rising and spreading over and intruded into the overlying

Paleozoic rocks, as its source is evidently far beneath these overlying rocks, its material could not have been derived from them.]

"Over the great mineral belt which lies between the Sierra Nevada and the front range of the Rocky Mountains, and extends not only across the whole breadth of that region, but far into Mexico, the surface was once underlain by a series of Paleozoic sedimentary strata, not less than twenty thousand feet in thickness, and beneath this were Archæan rocks, also metamorphosed sediments. Through these the ores of the metals were generally, though sparsely, diffused. In the convulsions which have in recent times broken up this long quiet and stable portion of the earth's crust (and which have resulted in depositing in thousands of cracks and cavities the ores we now mine), portions of the old table land were in places set up at high angles, forming mountain chains and doubtless extending to the zone of fusion below. Between these blocks of sedimentary rocks oozed up through the lines of fracture, quantities of fused material, which also sometimes formed mountain chains, and it is possible and probable that the rocks composing the volcanic ridges are but phases of the same materials that form the sedimentary chains." [Of the granite, perhaps, but not of the limestones.] "There is no particular reason why the leaching of one group should furnish more ore than the other, but as a fact the unfused sediments are much the richer in ore deposits. This is to be accounted for by supposing that they have been *the receptacles of ore brought from a foreign source.* We conclude that there has been a zone of solution below, where steam and hot water, under great pressure, have affected the leaching of ore bearing strata, and a zone of deposition above, where cavities in pre-existent, solidified, and shattered rocks became the repositories of the deposits made from ascending solutions when the temperature and pressure were diminished. Where great masses of hot lava were poured out, these for a long time remained too heated for ore deposition. So long, indeed, that the period of active vein formation may have passed before they reached a degree of solidification and coolness that would permit their becoming receptacles of the products of deposition. The masses of unfused cooler sedimentary rocks forming the most metalliferous mountains were, throughout the period of disturbance, in a condition to become such repositories. Highly heated solutions, forced by an irresistable power through rocks of any kind down in the heated zone, would be far more effective leaching agents than cold surface water, with feeble solvent power, moved only by gravity, percolating slowly through superficial strata."

"Richtofen suggested that the mineral impregnation of the Comstock lode was the result of the leaching of deep-seated rocks, perhaps the same that enclose the vein above, by highly heated solutions which deposited their load near the surface.

"Becker supposes the ore concentration to have been effected by surface waters flowing laterally through the igneous rocks, gathering the precious metals and depositing them in the fissure, as lateral secretion produces the accumulation of ore in the limestone of the lead region."

Prof. Newberry thinks Richtofen's theory the most probable of the two.

"For, first, the veinstone of the Comstock is chiefly quartz, the natural, common precipitant of hot waters, since they are far more powerful solvents of silica than cold waters. The ores deposited in the Mississippi lead region at low temperature contain little silica.

"Second—The great mineral belt alluded to between the Rockies and Sierra Nevada is now the region where nearly all the hot springs of the continent are situated. It is evident that these are the last of the series of thermal phenomena connected with the great volcanic upheavals and eruptions, of which this region has been the theater since the beginning of the Tertiary age, and it is evident that the number of hot springs in this region was once far greater even than it is now. That these hot springs were capable of producing mineral veins by materials brought up in and deposited from these waters, is demonstrated by the phenomena of the Steamboat Springs, where we have the best illustration of vein formation now in progress. The temperature of the lower workings of the Comstock mine is now over 150° F., and an enormous quantity of hot water is discharged through the Sutro tunnel. This water has been heated by coming in contact with hot rocks at a lower level than the present workings of the Comstock lode, and has been driven upward in the same way that the flow of all hot springs is produced. As that flow is continuous it is evident that the workings of the Comstock have simply opened the conduits of hot springs, which are doing to-day what they have been doing in ages past, but much less actively, that is, bringing toward the surface the materials they have taken into solution in a more highly heated zone below. Hence it seems more natural to suppose that the great sheets of ore-bearing quartz now contained in the Comstock fissure were deposited by *ascending* currents of hot alkaline waters than by *descending* currents of those which were cold and neutral. The hot springs are there, though less copious and less hot than formerly, and the natural deposits from hot water are there. It seems more rational to suppose, with Richtofen, that these are related as cause and effect rather than cold water has leached the ore and the silica from the walls near the surface. The fissure was for a long time filled with a hot solution charged with an unusual quantity of the precious metals, and the presence of gold in the wall rock is due to their being partly impregnated with the same solution."

"At Leadville there are no facts to prove that the ore deposits have been formed by the leaching of the overlying porphyry rather than by an overflow of heated mineral solutions along the plane of junction between the porphyry and the limestone. Near this plane the porphyry is often thoroughly decomposed, is somewhat impregnated with ore, and even contains sheets of ore within itself, but remote from the plane of contact with the limestone it contains little diffused and no concentrated ore. It is scarcely more pervious than the underlying limestones, and why a solution that could penetrate and leach ores from it should be stopped at the upper surface of the blue limestone is not obvious. Nor why the plane of junction between the porphyry and the blue limestone should be the special place for the deposit of the ore."

In place of Mr. Emmons' theory of the leaching of the porphyry by waters from above, etc., Prof. Newberry thinks that the Leadville ore deposits "can be better accounted for by supposing that the plane of contact between the limestone and porphyry has been the conduit through which *heated* mineral solutions, coming from deep-seated and remote sources, have flowed, removing something from both the overlying and underlying strata, and, by substitution, depositing sulphides of lead, iron, silver, etc., with silica."

If the porphyry is so rich in precious metal as Mr. Emmons' assays report it to be, Prof. Newberry thinks it "a remarkable and exceptional case of the diffusion of silver and lead through igneous rocks." He thinks it possible that the Leadville porphyries are phases of rock rich in silver, lead and iron, which underlie this region, and which have been fused and forced to the surface by an ascending mass of deeper seated igneous rock; "but even if the argentiferous character of the porphyry shall be proven, it will not be proven that such portions of it as here lie upon the limestone have furnished the ore by the descending percolation of cold surface waters. Deeper lying masses of this same silver, lead and iron-bearing rock, digested in and leached by hot waters and steam, under great pressure, would seem to be a more likely source of the ore." He argues also that if the overlying porphyry had yielded, by leaching, such enormous bodies of metal as we find in the Leadville ore bodies, we should find the porphyry a much more rotten, "digested kaolinized and desilicated rock than it is. As a rule it is generally quite compact, except in a narrow line near the ore body, where it is much decomposed, probably by hot chemical solutions forced up from below, along the plane of contact. It is difficult to understand why the upper portion of the porphyry should be so solid and homogeneous, with no local concentrations or pockets of ore, if they have been exposed to the same agencies as those which have so changed the under surface."

He thinks also that if the ore bodies were derived by leaching of the porphyry by surface waters, there ought to be evidence of its continuing in the present day as it does in some galena mines. Dr. Newberry admits, in a modified form, the general truth of the "lateral secretion" theory in some instances, but does not think that the vein materials are necessarily derived from the wall rock immediately opposite the places where the ore is found. He considers the main influence of igneous rocks is rather in supplying heat to the solutions than directly supplying the elements of the ore, and he mentions a case in Utah where ore-bearing quartz veins come up on either side of an unaltered, hard dyke of igneous rock, from which there is no evidence that they derived either their quartz or their metal from the dyke or adjacent limestone, but from heated solutions ascending from a deeper source and bringing up foreign material with it. He considers Richtofen's theory of the filling of the Comstock to be the true one, and the phenomena furnished by Steamboat Springs to give us the typical mode in which most metallic veins were formed and filled.

LE CONTE'S THEORY.

Professor Le Conte, in his geology, says of fissure veins, that they are fillings of great fissures, produced by movements of the earth's crust. When these fissures are filled, at the time of formation by igneous injection, they are called dykes, when subsequently with mineral matter by a different and slower process they are fissure veins. They often outcrop like dykes for miles over the surface of the country by reason of their superior hardness to the enclosing country rock, and extend to unknown but certainly very great depths. They also occur in parallel systems.

The leading characteristics of true fissure veins he defines to be:

1. Their continuity for great distances and to great depths.

2. Their occurring in parallel systems.

3. Their filling a pre-existent fissure, the distinction between vein and wall rock being usually quite marked.

4. The presence of selvage or gouge between the gangue and the country rock, which he attributes to water circulating in the fissure.

5. Their contents are more varied than those of other classes of ore deposits.

He distinguishes *infiltration veins* and *great fissure veins*, the former occupying a small short crack in the strata, deriving its filling from material oozing from the sides by *lateral secretion* from a single variety of rock. The latter occupy great and deep fissures, and derive their contents from *all* the strata to great depths, and especially from the deeper *strata*. Hence the contents of these veins are more varied.

"The contents of mineral veins were deposited by hot alkaline solutions coming up through fissures, in other words hot alkaline springs. Deposition by solution is proved by the occurrence of banded or ribbon structure and interlocked crystals and combs, by quartz forming the gangue, and that quartz of the kind known to be only formed by water solutions by its containing bubbles of water inside it, etc.

"That the solutions were hot is implied by the great depth to which the fissures are known to descend and the regular increase with depth, of the heat of the earth. Hot water is also a most powerful solvent. That the solutions were alkaline is implied by the fact that alkaline sulphides and carbonates are the only solvents of quartz. The same character of water when carbonic acid is in excess, dissolves carbonate of lime and baryta, the other common forms of gangue. Hot springs of this kind in Nevada are to-day depositing quartz and iron and lime and filling fissures."

He considers that the ore or metal materials came in with the same solutions that brought in the dissolved quartz, lime or baryta gangue. He considers that great fissures have been formed by deposit from hot alkaline waters holding various mineral substances in solution. The more insoluble substances are deposited in the vein, while the more soluble reach the surface as mineral springs, and he quotes the already described phenomena of the Steamboat Springs, near Virginia City, Nevada, as a fissure vein forming before our eyes, and explaining to our vision the way in which fissure veins have in former ages probably been formed.

He sums up by saying that: " Meteoric waters circulating in the interior of the earth in any direction, downward, upward, or laterally, deposit slightly soluble matters in their course, in cracks, cavities or great fissures, forming fossil casts, geodes, amygdules, infiltration veins and fissure veins.

"As to direction—the up-coming waters, especially in metamorphic and volcanic regions, deposit most freely, because they are hot and alkaline, and therefore powerful solvents and cool gradually on approaching the surface. But that downward percolating waters may also deposit metallic ores is proved by the fact that these are sometimes found hanging like stalactites from the roof of cavities. The great fissure veins are the most prolific because these fissures are the highways of water from the heated depths. But every kind of water-way will receive deposits, and as the kinds of these are infinitely various, and pass by insensible gradations into each other, so also will be the veins that fill them. The open fissure is the easiest, and therefore the most traveled highway. In these, therefore, we have the most perfect type of veins, with their banded structure, their selvages (or gouge), their great size and continuity. But in many cases crust movements produce only slight fissures or loosening of the rocks along planes full of small cracks with country rock between. These loosened planes become also water-ways, and, by deposit, form those irregular veins so common everywhere, but especially in the cinnabar veins of California.

"Or again, crust movements may produce not clean, open fissures, but rather planes of shattered rock like fissures filled with rubble. Deposits in such a water-way forms a breccia of country rock, cemented with vein stuff.

"Or again, in certain country rocks, soluble in water, especially limestones, the rock is dissolved along the water-way and the vein stuff deposited '*pari passu*,' giving us the *substitution veins*. In short, if one can conceive clearly that mineral veins are filled water-ways, all these complex phenomena solve themselves."

PART III.

PRINCIPAL COLORADO MINING DISTRICTS.

BOULDER COUNTY.

The mines are situated on the Eastern slope of the Colorado range. The mining district is about thirteen miles long by four to ten wide (not including Caribou Hill).

GEOLOGY.

Along the foothills adjoining the plains is a series of "hogbacked" ridges formed by the upturned floor of the prairie, consisting of Triassic, Jurassic and Cretaceous strata, resting on the Archæan granite core of the range.

These upturned sedimentary beds of sandstone, limestones, clays and shales form a fringing belt, varying in width and dip, along the entire extent of the Eastern foothills.

South of Boulder their dip is almost vertical, forming near South Boulder Cañon a magnificent peak 3,000 feet above the plains.

The Upper Cretaceous or Laramie group contains valuable coal beds, whose outcrops, owing to erosion at Boulder, are some miles out on the plains.

These hogbacks also supply excellent building stone, flagstones, fire-clay and lime.

They are barren, however, of precious minerals, both here and generally along the Eastern foothills.

The Archæan granite rocks immediately adjoining the plains have also, as a rule, been found to contain but few valuable minerals.

A few copper stains and some local stains and deposits of copper are nearly all that is found. It is not until the range has been penetrated for a distance of several miles that productive deposits appear.

In Boulder County we have the nearest mines to the plains, they being not more than two miles distant.

The Archæan rocks consist principally of a granite-gneiss, showing indistinct signs of primitive stratification. This is intersected by veins of pegmatite, or very coarse, crystalline, and sparry granite, varying in width from a few inches to 40 or 50 feet. Their composition is the same as granite, consisting of white feldspar and quartz, with very little mica; in other words, granite in a

MAP OF COLORADO PROSPECTING GROUNDS AND MINING REGIONS

PLATE XI.

coarser and more crystalline, sparry condition than the adjacent country rock and with less of its mica.

Two of these veins, the Maxwell and the Hoosier, are strong and well defined, traversing the district for several miles. The Maxwell runs East of North, crosses the road two miles from Boulder on the way to Sunshine, and is easily visible from its reddish, white and rusty color. It carries pyrites and tellurides. The Hoosier vein, or rather gangue, forms the western limit of the telluride belt, is 30 feet wide, and runs through Gold Hill in a direction East of North. It carries silver ore and gray copper.

The Telluride belt underlies the Magnolia, Sugar Loaf, Gold Hill and Central districts. Eruptive rocks are scarce in this belt, but "pegmatite" veins abound.

West of this region enormous masses of eruptive rock occur, and tellurides are not found.

In the Caribou district are rich silver ores, carrying 300 to 1,500 ounces silver to the ton. In the Ward district veins carry free gold, with iron and copper pyrites, which have a general direction East and West, while the others are more nearly North and South. Of eruptive rocks, that which forms the Sugar Loaf, a conical hill between Four-Mile and Boulder Creeks, is a fine-grained porphyritic rock, of a grayish color, showing small, white feldspars, black mica and hornblende, and crystals of titanic iron, with a little augite. The crystalline ground mass in which these crystals are set consists principally of feldspar, with a little quartz. A similar rock is on Four-Mile Creek, showing large feldspar crystals. This rock is a massive eruption of considerable extent. A dense black rock not unlike basalt occurs east of the Sugar Loaf, in a dyke, and is called diabase.

At Jimtown a quartz-diorite dyke occurs, of light color, containing much hornblende and titanic iron, running nearly through the street of the village. The cliffs at Jimtown, over 500 feet high, are quartz porphyry, of a white color. It consists mainly of large crystals of quartz and feldspar, set in a fine-grained crystalline ground mass or paste.

MINES.

Boulder mines are celebrated for the occurrence of Telluride minerals, some of the richest and rarest ores occurring in nature. The Telluride belt occupies the eastern part of the district, and extends to within a short distance of the sedimentary "hogbacks." It comprises the Magnolia, Sugar Loaf, Central and Sunshine districts. West of this belt no tellurides occur.

In Caribou district the ores are rich argentiferous galena, with many varieties of other rich ore, stephanite, proustite, and others. In the Ward district pyrites abound, and where it is decomposed free gold is found. The pyrites, though gold-bearing, is difficult of reduction.

The Boulder district contains very rich ores, yet development has been irregular and production uncertain, due partially to the irregular manner in which the ores occur. Of late, mining has been resumed at Caribou, with prospect of steady output.

The veins, that is the "pegmatite" gangues, are called true fissures, and stand at a high angle and are often very wide, but the rich ore is concentrated in thin streaks and not very continuous bodies. Of the character of the fissure veins Mr. Emmons says, "If the term 'true fissure' means a vein which occupies what was once a deep-seated, wide-gaping fissure, filled in by vein matter and ore, coming from unknown depths, and distinct and foreign to the material of the adjacent country rock, there are no such true fissure veins in this district," and we might go further and add nor in Colorado generally.

The gangue or vein material is simply an alteration of the adjacent granite or gneissic country rock, as testified by its composition, which is quartz, feldspar and some mica. This is impregnated with rich mineral, whose source we venture to say is not far to find, microscopically or chemically diffused in an adjacent country rock of porphyry, and concentrated in the sparry material.

This impregnation has taken place either along the contact of an eruptive porphyry rock with the country rock granite, or else in a pre-existing vein of pegmatite, or along some fault or jointing plane in the country rock itself, which has been favorable to the concentration and precipitation of metallic minerals from their solutions. This account will fit many of the so-called "true fissure veins" in Colorado. The direction of the vein is generally between North-East and North-West, in the Ward district East and West. Their dips are mostly very steep or vertical.

TELLURIDE ORES.

The quartz or pegmatite gangue impregnated with telluride ore has generally a pale, bluish-gray and rather greasy appearance, streaked here and there with a dull, blackened, greasy stain upon which sometimes the true telluride minerals can be seen, such as sylvanite, which occurs in long, thin crystals of a bright, tin-like appearance. It is sometimes called graphic tellurium, because the crystals crossing one another assume the form of Hebrew writing characters. It is a telluride of gold and silver.

There are many varieties of telluride ores, some rich in silver, and other in gold, and some with both combined. When a piece of the gangue containing tellurium is roasted, the gold will come out in good-sized globules on the surface. This used, in early days, to be a much-coveted specimen for those who wanted to possess a piece of Colorado gold in the rock itself.

Hessite, petzite, Coloradoite, and native tellurium are among the varieties of tellurides.

Central District. The "Golden Age" mine, near Jimtown, is at the contact of porphyry and granite. The vein is 40 feet wide. The ore comes from a streak of white quartz, one to two feet thick, sometimes very rich in free gold. Pyrites also occur. Rich concentrations of ore are found at intervals, some ore as high as $30 per pound; average ore mills $20 per ton.

Gold Hill district is in the telluride belt traversed by the Hoosier gangue. Several of the veins cross the Hoosier gangue, and are richer in its vicinity. The Red Cloud's vein is three and one-half feet wide. The ore was telluride at the surface, passing into auriferous pyrites with depth.

Sunshine, also in the telluride belt. Its ores are lower grade. Free gold and tellurides occur on the surface, passing into pyrites with depth. The American, Grand View and others are among the principal mines.

Sugar Loaf, also in the telluride belt, is an enrichment of the Hoosier gangue, the gangue being pegmatite.

Magnolia district. In the Keystone mine is a narrow deposit, six to seven inches wide, yielding Coloradoite (telluride).

Ward district is outside of the belt, and carries copper and iron pyrites bearing gold, some of which mills $60 per ton on an average.

Caribou. The Caribou mine has yielded a great deal of silver. Its ores are a mixture of galena, chalcopyrite and zincblende, occurring in gneiss near a dyke of eruptive diabase. The Caribou mine has produced two millions of dollars.

The "No-Name" is said to cross and fault the Caribou. The ores are silver-bearing, but also carry gold. Ores are silver glance, stephanite, gray copper, argentiferous galena, copper pyrites. Native silver is common, also some ruby silver. Copper pyrites carry more gold than silver.

Prof. van Diest considers that the granite rocks near Boulder are thrown into a series of parallel folds, "first a great fold following the Continental Divide, prominent near Gold Hill; another near North St. Vrain, and a third between Middle and South Boulder. Also, two prominent side folds cut these main folds diagonally, one running from Ballarat to Jimtown, the other from Sugar Loaf to Gold Hill. The telluride veins run along the slopes of these folds."

He appears to associate the veins with cracks and fissures coinciding with this folding. "Some of the main fissures being filled at once by porphyry dykes, the others more gradually by vein material." "The veins," he says, "occur along, on, and near these dykes, along lines at the junction of the more massive granite with the stratified gneiss, along and between stratification planes of schist, and along the joint planes of granite."

He attributes the veins to percolating alkaline waters dissolving metalliferous material and veinstone from the surrounding rocks. Alkaline springs, he observes, still exist in the neighborhood, as they do in the mining district of Idaho Springs. "The veins occur where the foldings are abrupt, and the direction of the veins is parallel to the strike of the stratification. As a rule, the veins in Boulder County are not of great extent; a single vein can rarely be traced on the surface or beneath it for more than 600 feet. Before that distance is reached the vein spurs off into another vein, follows it for a while, and spurs off again into another.

"Where veins cross at a small angle or where a spur branches off from the main vein, accumulation and enrichment of ore takes place. There are two courses of veins, one East and West, the other North-East by South-West. The former system appears to be the oldest, as the latter faults it.

"The ore occurs in chimneys or pockets, with a good deal of nearly barren ground between. Small veins run parallel with each other for some distance, the interval filled with granite or pegmatite. Sometimes a vein pinches out entirely. The ore streak is from 1 to 20 inches wide, containing more horn-quartz than the country rock. Some of the veins interlace like arteries in a body. Minute particles of pyrites (marcasite) often produce a dark stain in the telluride quartz. By moistening the stone the telluride minerals and pyrites appear distinctly."

ORE DEPOSITS OF JIMTOWN.

BOULDER DISTRICT.

Jamestown or Jimtown mining camp lies a little north of Boulder, its ores are largely gold-bearing and a great dyke of porphyry passes through the street of the village up onto the mountain containing the mines. Mr. John B. Farish gives an interesting account of one of the typical mines called the Golden Age, from which we extract as follows:

"Leaving the little village of Jimtown, located in the cañon of James creek, the road winds up a steep mountain composed of coarse gray granite and belts of gneiss. Here are located the Golden Age and Sentinel mines. The Golden Age location covers the outcrop of a quartz-porphyry dyke which cuts through the granite with a strike of north 70° east. This dyke varies in width from a few feet to about fifty, and dips south with an angle of 45°. The outcrop of the main ore chute on the Golden Age is marked by a line of surface works extending along the contact on the lower side of the porphyry dyke from the line shafts on the east to the main shaft on the west.

At a depth of about 100 feet the main shaft discloses a split in the vein. The upper or hanging-wall streak called "the hanging-wall vein," continues into the dyke on about the same dip, but with porphyry hanging and foot-walls, until a depth of 330 feet is reached, where it enters the upper contact between the porphyry and granite, and remains in it to the bottom of the main shaft, 470 feet on the incline below the apex. The Adit tunnel cuts the porphyry dyke about 250 feet below the bottom of the shaft, and shows this streak in the same contact.

Below the split the lower, or foot-wall streak called the foot-wall vein, stands a little straighter, and at the second level, 180 feet below the surface, is found on the contact between the under side of the porphyry dike and the granite foot-wall. It remains on this contact generally, though occasionally it is found only on the granite, down to the bottom of the shaft.

The porphyry dikes vary both in width and dip. On the third level it is forty-seven feet wide, and in the adit only eight feet. It has been much acted upon by vein-forming agencies, mineral structures, etc., on the upper workings, and is much decomposed. In the adit it is more compact and unaltered and shows considerable pyrites.

The Golden Age veins are well defined, presenting a typical banded or ribbon structure. They are inclosed in distinct walls with gouge and slickensides. The seams and feeders that radiate from the veins come in from the porphyry dike. The ore from the Golden Age veins is remarkable for its very rich specimens of free gold. The ore is a typical free-milling ore, a good per centage is saved by amalgamation on copper plates, the resulting bullion being over 900 fine, and the tailings yield iron concentrates of fair grade. As a rule it is, especially when rich, a hard, flinty or vitreous-appearing white quartz. The gold, especially in the hanging wall vein, is seldom accompanied by pyrite or any of the baser minerals. It is generally imbedded in the white quartz, as bright yellow gold, in size from coarse grains to nuggets often several ounces in weight. One specimen contained seventy ounces of gold in one piece. The "foot-wall vein" contains more of the base metals than the hanging-wall. After it reaches the lower contact between the porphyry and granite, there is a marked increase in the quantity, which is still further increased when it leaves the contact and enters the granite. In such places blende and galena appear in small quantities, with pyrite and much copper pyrites, but the ore retains its value in free gold. One small stope on the foot-wall contact is said to have produced, besides the mill ore, specimens which, when amalgamated by hand, in a mortar, yielded gold bullion to the value of $25,000, leaving tailings sufficiently rich to ship to the smelters. In none of the openings were any tellurium minerals found, nor do they occur in the Golden Age vein.

Returning to the surface the Sentinel mine location covers the apex of a vein enclosed in a belt of schistose or gneissic rock. It lies nearly parallel to and about 100 feet south of the apex of the Golden Age veins. Only two shallow openings have been made on this vein on the surface, the deeper, a shaft sunk 30 feet. In driving the Adit tunnel the first vein encountered was the Golden Age on the hanging-wall contact of the dike and about 175 feet further to the north the Sentinel vein was reached in granite. An uprise of this vein from the main shaft demonstrated that the vein dips at an angle of 70° *passing through* the Golden Age vein on its course.

The Sentinel vein produces an ore entirely distinct from that of the Golden Age. It is the characteristic bluish quartz of the tellurium veins of Boulder county with the characteristic chalcedony, quartz crystals and finely disseminated pyrites. The value is in metallic gold, petzite and sylvanite. While most of the gold was deposited as native gold, a certain portion has evidently been rendered free by partial decomposition of the sylvanite. This ore is very rich; one specimen recently found weighing two pounds is valued at $228, while shipments of first class ore are made to the smelters returning from 10 to 17 dollars per pound. It is the practice in handling this high grade tellurium ore to amalgamate as much as possible in a mortar by hand and ship the remaining tailings. As illustrating this I will cite one lot selected at random of 17⅜ pounds, which yielded $200 in bullion and then netted at the smelters $80.60, the assay on the tailings being 435 ounces gold and 84 ounces silver to the ton.

The richest ore usually occurs in two seams or narrow streaks, often from a foot to, at times, as much as ten feet apart. The intervening space being more or less mineralized country rock. The miners leasing on this vein consider it richest where it is in the schistose rock, and poorest where it is in the porphyry on its course through the dyke.

So distinct are the characteristics of these veins that the crossing of the Sentinel through the Golden Age is plainly marked, being exposed on the main shaft and workings connected with it. The dip of the former as stated is about 70° to the southward and is regular, though at the points where it comes in contact with the quartz streaks of the Golden Age veins, it often follows along, without a break in its continuity, either above or below them for short distances before finally passing through and assuming its regular dip. Nor does the dip of the Golden Age veins appear to be much disturbed, the greatest vertical displacement noticed, being about 30 inches at a point where it is broken by the *passage through* it of the Sentinel veins.

The facts observed appear to confirm the opinion that the gold mines of Boulder county belong to at least two distinct periods of vein formation. To a first or earlier, can be assigned the Golden Age, the mines of Ward and other districts producing similar ores free from tellurium minerals. To a second or later, the tellurium gold veins for which Boulder county is particularly noted. That the ores from the Sentinel or tellurium veins are lower grade where the vein passes through the porphyry dike than elsewhere, is probably due to the formation of the Golden Age vein first. This has drained the dike of its disseminated mineral values. The Sentinel doubtless received its metal from the Schistose or gneissic rocks, and is consequently richer where enclosed in those rocks than when in the dike.

Prospectors look for richer or larger bodies of ore where veins unite or cross each other. In this property we have two interesting occurrences of this kind. The two Golden Age veins unite at a point 100 feet below the surface. These are similar veins of the same age. The result was the large and rich ore bodies mined in the stopes near the main shaft and adjacent to the junction of the veins. The other case—the crossing of the Sentinel tellurium veins through the Golden Age veins, the passing of later through earlier veins—produced no local enlargement or enrichment of the ore bodies. It is evident that to form such ore bodies, except in rare cases, the veins should be of contemporaneous origin.

GILPIN COUNTY.

The geology of the mines and veins of Gilpin County, which congregate around the vicinity of Central City and Black Hawk, resembles that of Boulder. The region consists of Archæan granite and granite-gneiss, penetrated by felsite and quartz porphyry dykes. The veins are here also only alterations of the country rock along certain planes, but do not occupy a once wide, gaping fissure. In some mines the vein material is a porphyry dyke. The vein of the Minnie mine is a felsite porphyry; of the Cyclops mine, a quartz porphyry. Dykes of porphyry occur near the lodes or in contact with them.

The veins have been traced to a considerable depth, over 1,000 feet, and in length over 3,000 feet. The direction of veins is between north and south and north-east and south-west. The dip is nearly vertical.

The ores are a mixture of iron and copper pyrites, very little galena, and some zincblende. All carry more or less gold.

There is also a silver district in the northern portion. The diameter of the gold district, which is quite distinct, is not more than 1½ miles.

In the gold veins the richer ore occurs in streaks not over one foot wide, in a compact, fine-grained mass of pyrite, copper pyrites being richer than ordinary iron pyrites. The rest of the vein, often many feet wide, carries pyrite irregularly, disseminated through decomposed country rock. The bulk of these ores are difficult to treat and are milled, the loss being 40 per cent. higher in the unoxidized, than in those completely oxidized.

The veins follow the cleavage planes of the country rock. These cut the stratification planes at right angles, with a vertical dip. It is supposed that the porphyry dykes are older than the veins, as the cleavage intersects the porphyry equally with the other strata.

The interval between these mining districts and the plains, usually 20 miles or more, is commonly barren of precious minerals.

The Gregory, Bobtail, Burroughs and others are among the mines of note.

CLEAR CREEK COUNTY.

"The geology of this adjacent district is much the same as that of Gilpin county, The country rock is Archæan granite and gneiss, traversed by porphyry dykes. The fissure veins are also alterations of the country rock along a jointing or faulting plane and are frequently in direct connection with porphyry dykes which form either one or the other wall of the vein and sometimes constitute the vein material itself. In other cases the mineral vein is an impregnation of a pre-existing pegmatite vein in the gneiss."

"The ores are silver-bearing and derived from argentiferous galena and gray copper. Where pyrites abound the ore yields both silver and gold. The rich ores are smelted. A large proportion is concentrating ore which impregnates the country rock at a greater or less distance from the main crevice, usually on the foot-wall side.

The porphyry filling or gangue of the Colorado Central vein assays 0.063 oz. of silver to the ton, and a trace of gold.

Georgetown, Idaho Springs and Geneva Gulch are the centers of the principal districts.

Geneva Gulch and Hall Valley though not in Clear Creek county belong to the same mineral belts."

Obsidian dykes occur in the Colorado Central vein parallel with the vein, which is a porphyry dyke, there is therefore a dyke of obsidian within an impregnated dyke of porphyry, and the richest mineral is close to that obsidian.

The Centennial has one wall porphyry, the other not found, and the mineral lies close to and impregnates the porphyry, fading out in the same rock. The porphyry assays a fraction of an ounce gold and silver in the Centennial. Feeders come in, and the best ore is between the feeders, but not in the feeders themselves. The ores are copper and iron pyrites, and, near the granite, zinc and lead.

In the Colorado Central mine faulting seems still progressing. Mr. C. Gehrman tells me they are obliged to re-timber the mine every now and then in consequence of the foot-wall rising. Some of the Georgetown veins between walls are quite large, (from 50 to 100 feet,) but the pay streak, though rich, is small in proportion.

The Centennial vein is large and carries plenty of ore, but not of very high grade. There are three main porphyry dykes in the region with branches from them. The gold ore keeps near the porphyry and is an impregnation of it.

MINES OF CLEAR CREEK COUNTY ABOUT IDAHO SPRINGS.

Mr. W. H. Wiley, M. E., kindly gives me the following information with regard to the veins in Clear Creek county in the neighborhood of Idaho Springs:

"The trend of nearly all our veins is about north 70° east. There are a few north-west veins usually of little value. The dip is nearly always northerly varying from perpendicular to within 30° of horizontal. One notable exception as regards the dip, is the Victor-Granthan vein on Seaton Mountain above Idaho Springs. This is a flat vein dipping south and intersecting a number of older veins.

"Our veins vary in width from a few inches to over 100 feet. Many are merely alterations of the country rock, a widening by chemical action of a small mechanical fracture causing frequently a gradual transition from distinct crevice material to unaltered country rock. Others are characteristic fissure veins between defined walls. Porphyry dykes are of frequent occurrence, they usually agree in direction with the course of the veins, or rather the veins correspond with the dykes, as the dykes were usually the first formed.

"One exception to this is the Stanley-Whale vein, where in one place a porphyry dyke cuts squarely through the vein. In another place the porphyry is intrusive in the vein material, and near by, fragments of the same porphyry are cemented together with mineralized matter. The vein was formed and mineralized, the porphyry came next, and then there was a later deposition of ore. An interesting phenomena in some of the old workings of this (the Whale) mine, is that the mineralization is now going on. The waters of this mine are strongly charged with mineral matter, and in flowing down the foot wall, this matter is being deposited. Much of this is silica. The recently formed is gelatinous and in places this soft material has a distinct crystalline form.

"The Mattie vein has been opened up for nearly two miles in length, its direction is N. 50° E., its dip 76° from the horizontal. It is remarkably regular both in slope and dip. It is in places a contact between a porphyry foot-wall and a granite schist hanging wall, and in other places the porphyry dyke, some twenty feet in width, is mineralized, and constitutes in itself a vein. Two adjacent mines on this vein, the Mattie and the General Thomas, are very similar in vein character, except that the value of the Mattie ore is mainly in silver, while the other is almost wholly in gold. The direction of the Lamartine mine vein is N. 76° E. Its dip is nearly vertical and changeable, so that it dips in opposite directions at different depths. The enclosing walls are granite. The ore body, out of which a million dollars was taken in a year, extends over but a limited amount of the vein, and varies in width from two to eight feet. It seems to have been caused by the union of several veins."

SUMMIT COUNTY.

"The high mountain portion of this county consists of Archæan granite rocks. But along the valley of the

Blue river, fragmentary beds of the Silurian, Carboniferous, Triassic, Jurassic and Cretaceous periods occur which have escaped erosion, relics of a former connection of the seas which filled the South and Middle Parks.

These rest on the Archæan of the Park Range, and are repeated on its West side, the Park Range having been lifted up by the great fault movement so well defined in the Mosquito Range.

Along the upper portion of Eagle river, Silurian and Carboniferous beds appear, dipping North and resting on the Archæan granite of the end of the Sawatch Range, associated with these are a great many eruptive porphyry rocks, the latter throughout this district show a marked connection with the relative richness in size of the ore deposits which occur all the way from the Archæan to the Triassic.

At the head of the Blue river, the Silurian, Carboniferous and Triassic formations have been much traversed by eruptive sheets, whose heat has caused matamorphism of the sedimentary beds. The beds are also much faulted, and the principal developments center around Breckenridge.

The "Helen" mine in French Gulch has ore as an impregnation of quartzite for 45 feet in width. The ore is free gold with some silver. The quartzite is rusty by the leaching out of the auriferous pyrites it originally contained. In the McKay mine argentiferous galena and carbonates of lead occur near an overlying bed of porphyry in a sedimentary rock."

The Monte Cristo mine on Quandary Mountain, has a deposit of low grade galena and zinc-blende, impregnating Silurian quartzite, its average is 15 oz. to the ton.

Veins occur at several points in the Archæan granite of the Mosquito range, but so far unimportant.

In Ten-Mile district the ores are mainly in the Upper Carboniferous limestones and sandstones, a higher horizon than at Leadville. This is an area of wonderful eruptive activity abounding in intrusive sheets and dykes of porphyry. The ores are rather low grade and refractory, consisting principally of pyrites mixed with zinc-blende. Most of the ore bodies occur in thin beds of limestone at their contact with a micaceous sandstone, more rarely at contact with a bed of porphyry or impregnating a dyke of porphyry. The last is best seen at the Pride-of-the-West on Jacques Mountain. The Robinson is the principal mine, its ore is a high grade argentiferous galena, associated with pyrites and zinc-blende, it occurs near the surface of a bed of gray limestone overlaid by white micaceous limestone, dipping N. 17°. The ore is a replacement of the limestone. The upper layer, consisting of pyrites and white mica, is a replacement of the overlying sandstone and is worthless. Below this the ore consists of galena and pyrites, extending to irregular depths in the limestone and in the larger bodies occupying its whole thickness. The greatest width of the ore chute, 100 feet, has been traced 1,000 feet following the dip. A crack or fault plane in the roof follows the line of the ore body and probably furnished the channel through which the ore solutions reached the limestone, as pyrites extend all through the fissure.

On Elk Mountain, ore is found in a thin bed of limestone at a higher horizon still than the Robinson, but it is poor in silver and it even extends up into the Triassic red sandstones. The "Pride-of-the-West," on Jacques Mountain, is a dyke of porphyry impregnated with baryta and ore.

On Eagle River, near Redcliff, argentiferous galena and carbonate of lead with iron oxide occur between limestone and porphyry or between limestone and quartzite. The limestones are carboniferous."

PARK COUNTY.

The basin plain of South Park is covered by sedimentary rocks of Triassic and Cretaceous age underlaid by Carboniferous and Silurian formations. These slope up to the crest of the Mosquito range on the West, but are apparently cut off abruptly against the Archæan granite on the East, probably by a fault. The coal beds of the upper Cretaceous occupy a portion of the center of the park around Como and stretch Southward to the Platte River.

Near Hamilton are deposits of hematite iron. Salt springs occur in the Southern end of the park, issuing from Triassic red sandstones.

In the north-east corner of the Park in the granite rocks, are the Hall valley and Geneva districts, a continuation of the Clear Creek silver belt system. In the "Whale" mine the gneiss is intersected by numerous veins of pegmatite. The lode runs north-east and south-west, and dips at 65°. It is a thin vein of baryta and quartz, with irregular bunches of galena and gray copper, the latter very rich in silver. The crevice is 5 to 10 feet, but the vein proper, or pay streak, is from an inch to three feet wide. The altered walls are impregnated with pyrite, galena and zinc-blende. The principal mineral developments are along the eastern slope of the Mosquito range, and are derived principally from Silurian and Lower Carboniferous rocks. The order and succession of the lower, older or Paleozoic rocks composing this range are here seen, together with their average thickness.

First granite, forming the base and usually found at the bottom or on the cliffs of the deeper cañons; upon this rests:

			FEET.
Paleozoic.	Silurian.	Cambrian quartzite	200
		Silurian white limestone	200
	Carboniferous.	Lower Carboniferous blue limestone	200
		Middle Carboniferous, or Weber grits (sandstones and quartzite)	2,000
		Upper Carboniferous limestones, reddish sandstones and conglomerates	1,000
		Total	3,600

In some localities the total will reach 4,000 feet. These formations have been traversed by eruptive quartz porphyry, porphyrite dykes and intrusive sheets. The dykes occur principally in the Archæan, but the intrusive sheets are many, spread out between the quartzites and limestones of the Silurian and Carboniferous.

The connection between the eruptive masses and deposition of ore is very marked. "The ore bodies are a concentration of the metallic minerals originally disseminated through the mass of these eruptive porphyries, and now deposited along their plane of contact with the sedimentary beds, and extending more or less into the mass of the latter."

On Mountains Lincoln and Bross, in the principal mines, such as the Moose, Dolly Varden, Russia and others, the ores are mainly argentiferous, yielding galena and its products of decomposition, viz.: carbonate of lead (cerussite) and sulphate of lead (anglesite), with chloride of silver. Barite (heavy spar) is a common gangue or veinstone, especially in the richest part of the mine. Iron pyrites, decomposed and passing into a hydrated oxide of iron, together with a black oxide of manganese, give to the ore its rusty and black look.

The deposits occur in irregular bodies or pockets, often of great size, in the blue limestone, near its upper surface, but not always easy to find or follow. This limestone was originally covered by a sheet of quartz porphyry, which has been locally removed from the ore deposits, but exists in various parts of the Mt. Lincoln peak. The quartz porphyry is the variety called Mt. Lincoln quartz porphyry, and recognized by its large crystals of feldspar. The age of this porphyry is probably as late as the Cretaceous, as in the Gunnison, it is found breaking through rocks of that period. In the Dolly Varden mine the ore occurs in the limestone at contact with a vertical dyke of white quartz porphyry. In the Fanny Barret mine, on Loveland Hill, rich deposits of galena and anglesite occur in a vertical fissure or jointing plane traversing the limestone at right angles to its dip.

In Buckskin Gulch the Phillips mine is an immense mass of gold-bearing pyrites, deposited in beds of Cambrian quartzite near a dyke of quartz porphyry.

The Criterion, on the cliffs of the gulch, consists of large cavities in quartzite, occupied by both oxidized pyrites and galena near a green porphyry dyke.

The Colorado Springs mine has rich deposits of galena in the white Silurian limestone in close relation to dykes of diorite and quartz porphyry.

The London mine in Mosquito Gulch has two strong veins of pyrites carrying both gold and silver, the gangue of one is quartz, of the other calcite. They occur in the limestone in connection with an intrusive bed of white porphyry. These veins stand in a vertical position, the beds which contain them being turned up abruptly against the great London fault, by whose movement the Archæan granite rocks forming the eastern half of London Mountain are brought up into juxtaposition with the Silurian and Carboniferous beds at its western point. As we go South along the Mosquito range, the intrusive porphyries diminish in extent and with them also the mineral deposits.

In the Sacramento mine rich bodies of galena and rich decomposed minerals have been found in a series of pockets. Some of the cavities or caverns are empty, others contain sand and decomposed pebbles of ore, and others rich deposits. These deposits are not easy to follow with any certainty, open fissures lead up to the surface of the limestone. The limestone was originally capped by quartz porphyry which doubtless supplied the ore.

Placer deposits. The mountains bordering South Park, owing to great elevation, have been much exposed to glacial action. An enormous amount of detrital material has thus been accumulated in the valleys in the form of moraines, which, when re-arranged and concentrated by water, have formed valuable placer deposits.

The first placer gold was discovered in Tarryall creek in 1859, and in those days produced rich results.

Near Fairplay an immense amount of this material, probably resulting from the influence of several glaciers, is cut by the Platte river, exposing loose material for fifty feet. This has been worked for many years by sluice mining.

At Alma a gravel bed sixty feet deep is exposed on the banks of the stream which is at present successfully worked by hydraulic mining. Gold in flakes and small nuggets has been found all through this mass in paying quantities, but the richest deposits are found in the crevices and cracks of the bed-rock, which consists of a jointed bed of Carboniferous sandstone dipping gently.

It is customary to rip up this sandstone for four or five feet until a bed of more impervious clay is reached. No gold is found below this second floor. The gold is collected by quicksilver thrown into the flume daily, and afterward separated from the quicksilver by retorting it.

LAKE COUNTY.

The western boundary of this little county is the Sawatch range of Archæan granite, penetrated by dykes of porphyry. The slope of the Mosquito range on the east and the hills on the north, forming the water sheds between the Grand and Arkansas rivers, have a basis of Archæan granite and gneiss more or less covered by patches and remnants of Paleozoic formations, *i. e.*, Silurian and Carboniferous, which have escaped erosion.

Their lower portion relative to corresponding beds on the eastern or South Park side of the Mosquito range is due in part to faulting, and in part to folding of the beds.

Within these Paleozoic formations, these beds of quartzite and limestone, there is an enormous development of eruptive rocks principally quartz porphyries partially occurring as dykes, but generally as immense intrusive sheets following the bedding plane of the sedimentary rocks..

Glaciers have been at work also in this neighborhood. A huge "mer de glace" occupied the great valley of the Arkansas to whose bulk numerous side glaciers contributed, these glaciers have carved and sculptured the mountains. In the flood period following the first glacial epoch a lake was formed occupying the head of the Arkansas valley. The stratified gravel and sand beds which were deposited at the bottom of this lake now form terraces bordering the valley of the Arkansas river. These beds, known as "wash" or placer grounds, yield gold and are open to further development. Leadville is the center of the mining district, the ores are argentiferous galena and zinc-blende. They are smelting ores. Their value is increased by their having been oxidized, the lead occurring as carbonate, the silver as chloride in a clayey, or else siliceous mass of hydrated oxides of iron and manganese.

The ore is principally confined to the horizon of the "blue" or lower carboniferous limestone, covered by an intrusive sheet of "white Leadville quartz porphyry." The ore bodies occur not only at the immediate contact of these rocks but extend down in irregular pockets and chambers into the mass of the limestone, sometimes to a depth of 100 feet. Sometimes the ore completely replaces the limestone between two sheets of porphyry as in the "Col. Sellers mine," Chrysolite, Little Pittsburg, and on Fryer Hill. A few ore bodies occur, carrying more gold than silver, found at other horizons, usually as "gash" veins running across the stratification or along bedding planes. Such are the "Colorado Prince" in quartzite, the Tiger and Ontario in the Weber grits of the Middle Carboniferous.

The " Printer Boy," one of the oldest mines, has produced a good deal of gold, found as free gold associated with carbonate of lead and galena, passing down, as is usual in gold mines, into unaltered auriferous iron and copper pyrites, which occur in a body of quartz porphyry along a vertical cross-joint or fault plane in the porphyry. The gangue is a white clay resulting from decomposition of the quartz porphyry and though the clay ore is rich, it shows no minerals to the eye.

The Paleozoic formations together with the intrusive porphyry sheets sandwiched between them, have been compressed into gentle folds, and where the fold was at its greatest tension, a series of parallel faults have occurred having a general North and South direction, their uplifted side is generally to the East.

The prevailing eruptive rock is the "white Leadville porphyry," occurring generally above the blue limestone but also in places below it and at other horizons.

There are also other intrusive sheets of different varieties of quartz porphyry. The ground is generally buried beneath a hundred feet of glacial moraine material, locally called "wash."

The general geology of the South Park and Leadville region has been so elaborately traced by the labors of the U. S. Geological Survey that we cannot do better than give an abstract of their report in this connection:

GEOLOGY OF THE MOSQUITO RANGE AND LEADVILLE AND SOUTH PARK REGION (S. F. EMMONS).

The Rocky Mountains in Colorado consist of two parallel uplifts of Archæan rocks of granite, gneiss, etc., with conformable series of geological formations, from Cambrian to Cretaceous, resting upon their flanks, the later Tertiary alone being unconformable and resting on top of the upturned Cretaceous.

The eastern uplift is called the Colorado or Front range, the western the Park range. The depressions between them are called Parks.

The unconformity between the horizontal Tertiary and the uplifted Cretaceous and other beds shows that the great uplift of the ranges took place between the close of the Cretaceous and the deposition of the Tertiary.

The beds which we find uplifted and resting on the flanks of these ranges do not appear ever to have covered or enveloped the ranges of granite, but the latter formed the shore line or islands against which these sedimentary strata were deposited, and finally when the whole granite mass was uplifted the shore-line deposits were lifted with it and appear now as a fringe around the masses, which has suffered much since by denudation.

The Colorado range was the most extensive of these ancient land masses, extending from Pike's Peak to the boundaries of the State, 150 miles in length by 35 to 40 in width. North and South of this area it was continued by a series of islands and submerged reefs to the Black Hills of Dakota on the one hand and to the Territory of New Mexico on the other.

THE PARKS.

The present valleys of the North, Middle and South Parks were submerged in Paleozoic and Mesozoic times by the sea, and also in Tertiary times by fresh-water lakes. They formed a connected series of bays and arms of the sea and fresh-water lakes, as shown by the sediments of those eras still found in them.

In Paleozoic times the outlet of the North Park was towards the North, of the Middle Park toward the West, and of the South Park to the South.

Up to the close of the Cretaceous the North and Middle Parks were connected, forming a single depression. The present mountain barrier between the Middle and

South Parks did not extend as far as their western boundaries, and a water connection lay between them.

The waters of the South Park extended westward to the flanks of the Sawatch range.

In Tertiary times the Parks had been raised above the ocean level and were occupied by fresh-water lakes. Sedimentary beds were deposited in them, much of which have been denuded off. The western boundary of the Park area consisted of two distinct ridges or islands, forming a general line of elevation parallel with the Front range.

These are the Park range proper, on the West side of the North Park, and the Sawatch range, now separated from the South Park by the Mosquito range.

Between these was the Archæan mass of the Gore range, which formed, with the southern extremity of the Park range, the western wall of the Middle Park.

The present boundary of the South Park on the West is the Mosquito range.

Before the Cretaceous no Mosquito range existed. The rocks now forming its crest rested at the bottom of the sea.

The Sawatch range is the true continuation of the Park range proper, as an original Archæan land mass. The Archæan land mass of the Sawatch in Paleozoic times was an oval island about seventy miles long by twenty wide, surrounded by the Paleozoic seas laying down sediments against it.

Through the eastern portion of this area and parallel with its longer axis now runs the valley of the Arkansas River, which in Paleozoic and Mesozoic times did not exist.

Sections
to illustrate the gradual geological development of the
Leadville & South Park Region,
Colorado.

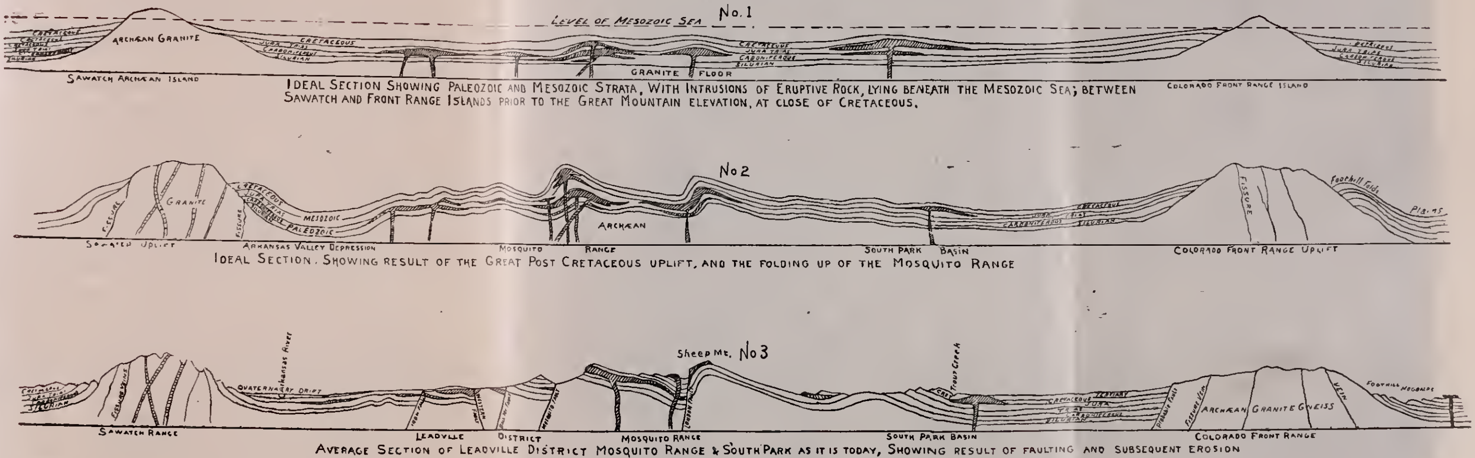


PLATE XII.

The height of these mountain masses above the adjoining valleys may have been far greater then than now, since the sedimentary beds surrounding them and numbering some 10,000 feet in thickness were formed out of material washed from their slopes. They were, however, probably not the only land masses at the time from which this material may have been derived, other land masses may have existed and have been washed away. The great lava flow of the San Juan Mountains may conceal the remnants of a former land mass of great extent.

The ranges were not uplifted by an upthrust from below, but by horizontal, tangential pressure, resulting from contraction of the earth's crust, caused by the cooling of its interior; this is shown by the folded character of the rock masses. The tangential crushing forces were applied in one case at right angles to the lengthwise direction of the mountain mass, in the other in a direction parallel with its axis, *i. e.*, North and South. As the forces of contraction became stronger and the folds were pushed closer together, the folds broke in enormous fractures or faults of many thousands of feet in depth, the forces being exerted on either side towards the central mass. Eruptive rocks poured out in many cases through these fractures and added to the mountain masses, and their ebullitions corresponded to the structural lines of greatest folding and faulting. Along the line of the Parks both earlier and later eruptions are so frequent that their outcrops form a continuous line. From the latter, the Elk Mountains, the head of White River, and the Elkhead Mountains in Wyoming, have apparently been the scenes of most violent and repeated eruptions during both the Mesozoic and Tertiary times.

MOSQUITO RANGE.

The study of this range is necessary to the understanding of the Leadville ore deposits, which occur on its western side. It comprises a length of 19 miles along the crest of the range, and in width includes its foothills bordering the Arkansas Valley on the West, and South Park on the East, a slope in one case of 7½ miles, and in the other of about 9 miles. All of this is about 10,000 feet above the sea level.

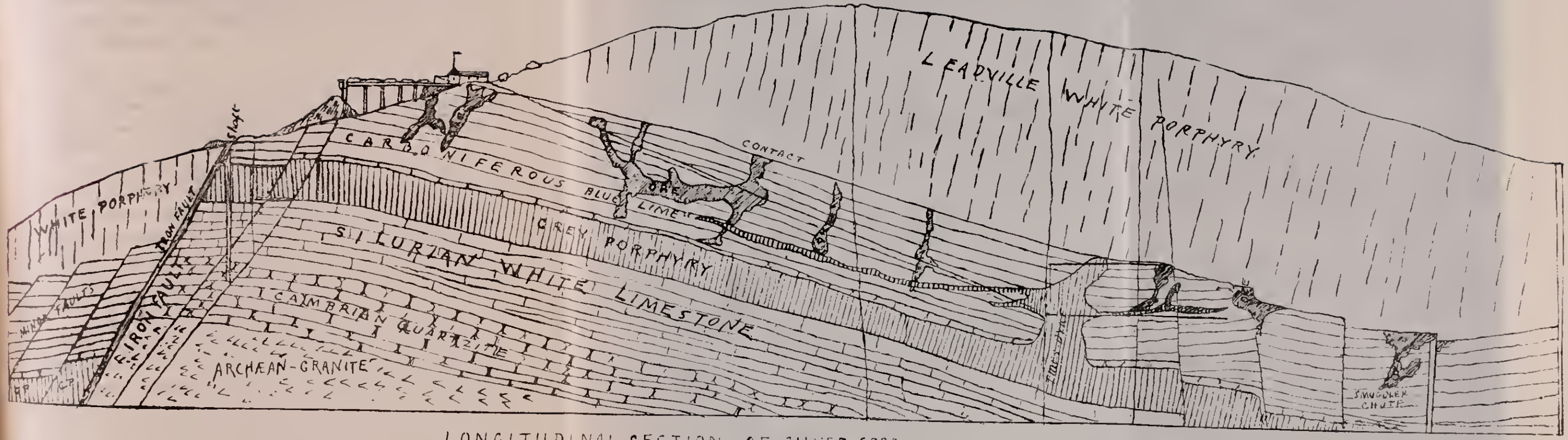
The range has a sharp, single crest trending North and South. To the West this crest presents abrupt cliffs descending precipitously into great glacial amphitheatres at the head of the streams flowing from the range. Mts. Bross, Cameron and Lincoln constitute an independent uplift. The abrupt slope West of the crest is due to a great fault extending along its foot, by which the western continuation of the sedimentary beds which slope up the eastern spurs and cap the crest, are found at a very much lower elevation on the western spurs. The jagged step-like outline of the western spurs is due to a series of minor parallel faults and folds.

The secondary uplift of Sheep Mountain on the Eastern slope is due to a second great fold and fault.

The elevation of Mount Lincoln is the result of the combination of forces which have uplifted the Mosquito range and those which built up the transverse ridge separating the Middle from the South Park.

The range has been sculptured by glaciers into cañons and the Arkansas valley is covered with horizontal terraces representing the distribution of material by waters, on the melting of the glaciers.

In the seas of the Paleozoic and Mesozoic eras which surrounded the Sawatch islands, some 10,000 to 12,000



LONGITUDINAL SECTION OF SILVER-CORD INCLINE. IRON HILL LEADVILLE

PLATE XIII.

feet of sandstones, conglomerates, dolomitic limestones and shales were deposited. Towards the close of the Cretaceous, eruptions occurred by which enormous masses of eruptive rock were intruded through the Archæan floor into the overlying sedimentary beds, crossing some of the beds, and then spreading out in immense intrusive sheets along the planes of division between the different strata.

The intrusive force must have been very great, since comparatively thin sheets of molten rock were forced continuously for distances of many miles between the sedimentary beds.

That the eruptions were intermittent and continued for a long time is shown by the great variety of eruptive rocks found. That this eruptive activity preceded the great movement at the close of the Cretaceous which uplifted the Mosquito range as well as the other Rocky Mountain ranges, is proved by the folding and faulting of the porphyry eruptions themselves.

In the period intervening between the close of the Cretaceous and the deposition of the Tertiary strata, during which the waters of the ocean gradually receded from the Rocky Mountain region, the pent-up forces of contraction in the earth's crust, which had long been accumulating, found expression in dynamic movements of the rocky strata, pushing together from the east and the west the more recent stratified rocks against the relatively rigid masses of the Archæan land, and thus folding and crumpling the beds in the vicinity of the shore lines.

The crystalline and already contorted beds of the Archæan doubtless received fresh crumples in this movement.

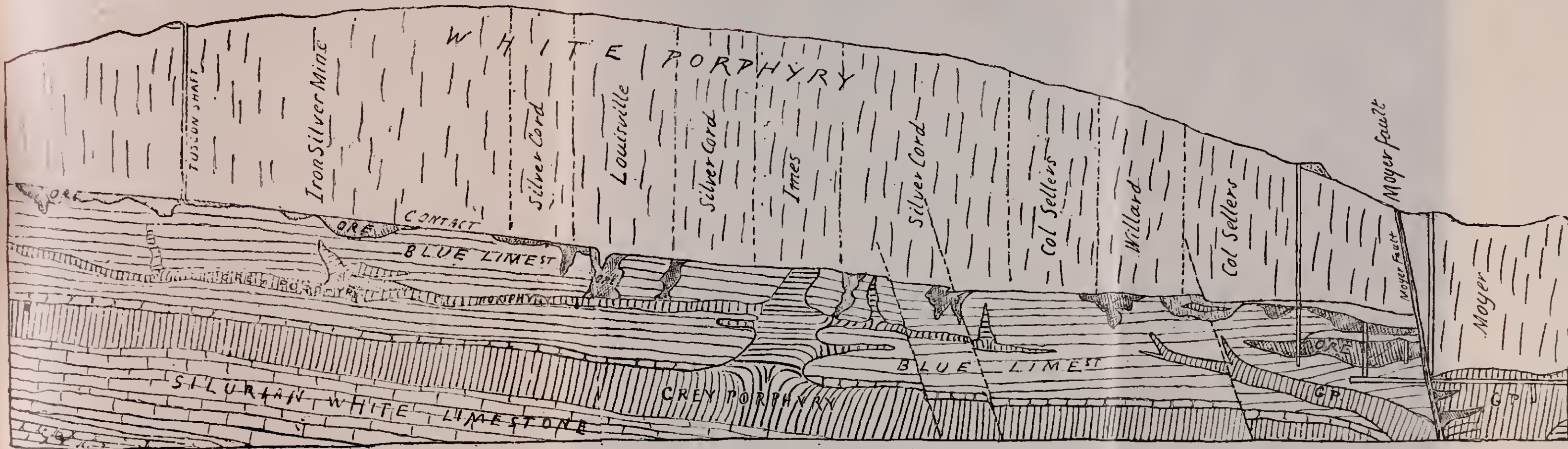
A minor force also acted north and south, producing gentle lateral folds along the foothills at right angles to the trend of the range. These movements were not paroxysmal or sudden and violent, but protracted for an enormous lapse of time, and appear to be continued in diminished force up to the present day.

MINERAL DEPOSITION.

It was during the period intervening between the intrusion of the eruptive rocks and the dynamic movements which uplifted the Mosquito range, that the original deposition of metallic minerals occurred in the Leadville region, probably in the form of metallic sulphides, though now they are found largely oxidized and in other combinations. They were probably derived from the eruptive rocks themselves, and are therefore of later formation than them. Their having been folded and faulted with them shows that they must have been formed before the great Cretaceous uplift, and therefore that they are older than the Mosquito range itself. The deposits were formed by the action of percolating waters taking up certain ore materials in their passage through neighboring rocks and depositing them in a more concentrated form in their present position. This may have taken place while the sedimentary beds were still covered by the waters of the ocean, and the waters, therefore, may have been derived from it, or the area of the Mosquito range may have already emerged from the ocean and the waters have been estuarine.

STRUCTURAL RESULTS OF THE UPLIFT.

The uplift of the Mosquito range consisted of a series of anticlinal and synclinal folds fractured by faults.



CROSS SECTION OF GOLD-CHUTE
IRON-HILL LEADVILLE

PLATE XIV.

The crest is formed by the great Mosquito fault running north and south along the trend and axis of the range.

The other great fracture is the London mine fault running in a south-easterly direction along the eastern spurs of the range coinciding with a magnificent anticlinal fold seen on Sheep Mountain and in Sacramento Gulch.

On the western or Leadville side the folds, faults and cross-faults are more numerous, breaking the country up into a series of blocks and steps. The movement of these faults has been an upthrow to the east. The greatest movement is towards the center or Leadville region and dies out at either end north and south. In the middle region the aggregate displacement is 8,000 to 10,000 feet.

The crests of the folds and whatever cliffs may have been caused originally by the displacement, have for the most part been planed down by erosion. The erosive forces are best seen in the Arkansas valley which was occupied for over 100 miles by a grand 'mer de glace,' fed by numerous side glaciers from the adjacent ranges. There appears to be evidence in this region of two glacial epochs followed severally by two intervening eras of warmer weather. In the former, moraines were deposited by the ice, in the latter, by the melting of the ice, large fresh-water lakes occupied the broad valley of the Arkansas and have left relics of their former presence by extensive horizontal terraces and low table lands. This morainal matter together with the lake beds largely cover the mining area of Leadville and are called locally 'wash,' they also at several points afford broad gold placer grounds."

ORE CHUTES OF IRON HILL.

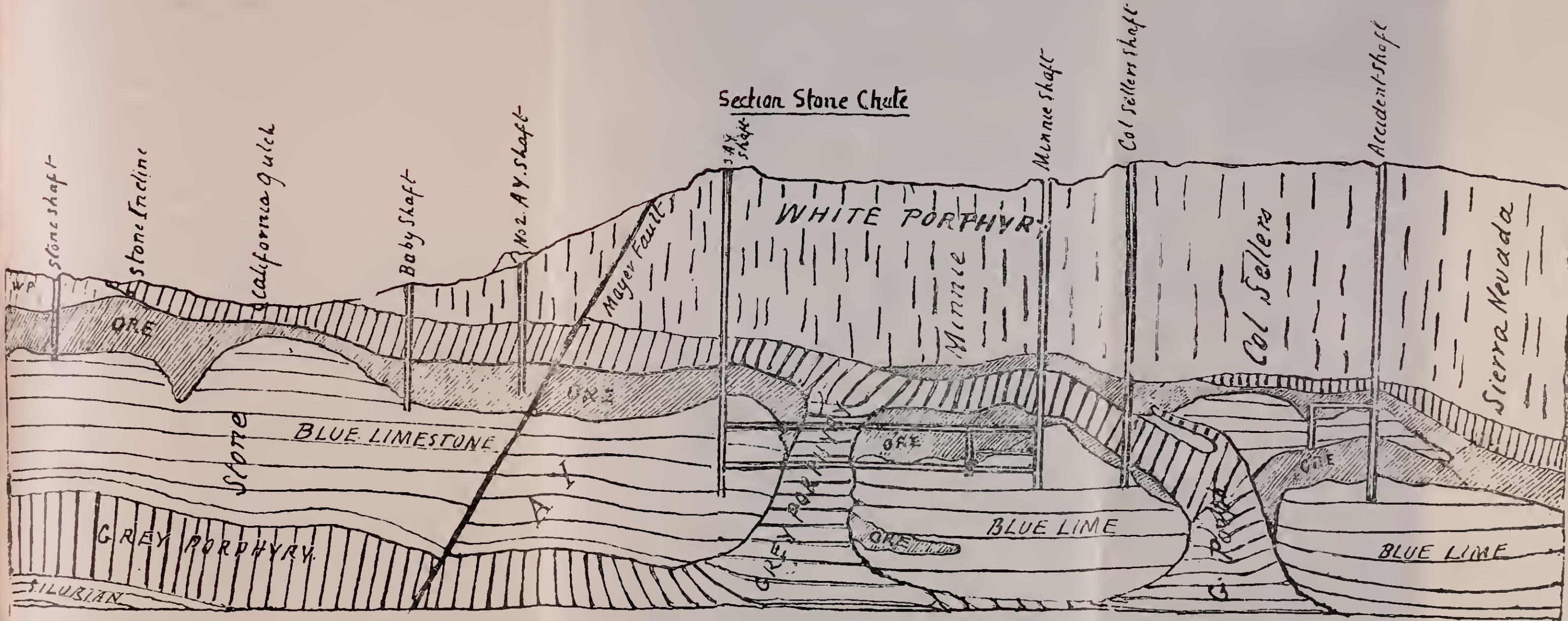
LEADVILLE, COLORADO.

FROM REPORT BY A. A. BLOW.

As typical of the mines of Leadville we may select those on Iron Hill, which have been very fully described by Mr. A. A. Blow. See plate Nos. 13, 14, 15.

Iron Hill is situated about two and one-half miles due east of the city of Leadville. It is the second of a series of flat top steps or bosses forming the western slope of the Mosquito range.

Iron Hill is a portion of the Cambrian, Silurian and Carboniferous, sedimentary formations found in the Leadville District, consisting of quartzite and two dolomitic limestones deposited at the bottom of the Paleozoic seas and resting upon the Archæan granites. Through and between these sedimentary rocks, were intruded at different periods, and from different vents or sources, two quartz porphyries or felsites. That the eruption of these porphyries occurred at long intervals of time, is shown by the distinctive characteristics of each, by their uniformly varying component parts, and further by the intrusion of one under, or into another with distinct planes of contact, and lines of demarcation. The oldest "white porphyry" or "block porphyry" chose for its plane of least resistance and deposition, the contact between the Lower Carboniferous blue limestone, and the Weber shales and grits, and forcing them apart, spread itself conform-



LONGITUDINAL SECTION OF STONE-CHUTE
IRON-HILL
LEADVILLE

PLATE XV.

ably over the upper horizon of the blue limestone, to a thickness of over one thousand feet in this locality. The vent or dyke of this white porphyry does not occur in this region. Though large dykes of it are found some miles distant in Four-Mile Cañon, where probably was the main vent. The contact of the white porphyry with the blue limestone may be regarded as the top of the horizon of Iron Hill, and the entire thickness of the latter as the vein rock or lead.

Some time later than the intrusion of the white porphyry, the eruption of the gray or dyke porphyry occurred. Breaking up through the lower formations, under great pressure, both from below and the thousands of feet of superincumbent rock above, it forced itself between the lower horizon of the blue limestone and the upper strata of the white limestone, and seeking the weaker lines of these sedimentary rocks, cut across their strata in the form of numerous dykes, from which again these sheets of intercalated porphyry of great extent spread between their bedding planes, and also between the contact of the blue limestone with its overlying white porphyry.

(Note.—It has been suggested that these intrusions of porphyry may have taken place coincident with the folding up of the strata, weak places along certain lines being thus formed by the movement, otherwise it is scarcely conceivable how a sheet of porphyry could intrude itself for miles between two sets of strata preserving an average thickness of not more than 20 or 50 feet).

It was during and after the eruption of these two porphyries and through these agencies that the ore bodies of Iron Hill were formed by a metasomatic replacement and substitution of the blue limestone from mineral bearing waters and vapors brought *from below* (according to Mr. Blow), and that these ore bodies having undergone secondary alteration and concentration were originally deposited, in the form of sulphides. Following the porphyry intrusion and as a result of the dynamic action of pressure and tangential contraction partly reduced by them, the movements which produced the folding and faulting of the Leadville district, and the elevation of the Mosquito range took place. The igneous and sedimentary rocks, as well as their enclosed ore bodies, all partook of this plication and faulting. The principal or major faults, like the Iron fault, having their axis nearly north and south, and parallel to the Mosquito range uplifts, while the secondary faults of lesser extent as the major fault, were generally at right angles to the former and east and west. Through these movements the several formations of Iron Hill were tilted to the eastward, dipping at an angle of about 14 degrees, for a considerable distance, but invariably flattening out and "basining up," upon approaching the next succeeding fault, and where such bending or synclinal form passed the elastic limit of the strata, breaking into minor faults or jointing planes, parallel to the general direction of fracture. Through subsequent erosion, the present surface contour of Iron Hill has been formed. The upper sedimentary formation of Weber grits has been entirely removed. The white porphyry being left as the surface or country rock. The successive thickness of the strata is as follows:

Top overlying white porphyry	600 feet.
Blue carboniferous limestone	200 "
Gray porphyry	150 "
White silurian limestone	160 "
Cambrian quartzite	150 "
Archæan granite	unknown.

FAULTS AND DYKES.

Iron Hill is bounded on four sides by four principal faults. On the west, the Iron fault with its strike nearly north and south. On the east the Mike fault parallel to it; and the other faults on the Moyer and Adelaide; the former connected with the Mike fault. From the parallelism between the dykes and the previous faults, it would appear that the dykes marked out the lines of least resistance, and subsequent fracture of the sedimentary beds, and the final minor faulting of these must have been the concluding and settling dynamic movement of the district. The gray porphyry forces itself in irregular tongues and dykes through the blue limestone up to the contact of the white porphyry above, where it flattens out into a long thick sheet, and at a lower horizon splits the bedding plane of the limestone in thin intercalated sheets. There are dykes and cross dykes, and dykes that cut one another, and others that intrude themselves in sheets between the strata, or split up into forked tongues. The sedimentary strata are very little metamorphosed or influenced by the heat of these eruptive intrusive rocks. The porphyry itself, however, is sometimes altered into Kaolin, at contact with the sedimentary beds.

The ore chutes and channels have a decided relation to the porphyry sheets and dykes. The depositson of ore near the dyke is generally in proportion to the magnitude of the dyke.

From the upper contact to the greatest developed depths, and to the very lowest strata, the substitution and replacement of the carboniferous ore-bearing limestone by ore and vein material has irregularly taken place in parallel zones.

Within these zones of replacement, the bodies of ore and vein material of Iron Hill occur in continuous chutes, or channels, occupying different horizons. The lower limestone replacements and ore bodies are more permanent than the contact or blanket veins. The former are associated with the intrusive sheets of gray porphyry.

Both the upper contact chutes and the deeper lime stone channels are the same, both having been formed from the same sources, only at different horizons, the one being always traceable into the other through numerous small cracks and ore crevices.

The replacements of the limestone on the upper contact are generally shallow deposits, of from 50 to 250 feet in width, and 1 to 20 in depth. In the deeper replacements of the limestone the ore bodies are much more irregularly distributed, occurring in lenticular masses and chambers, which are always connected by contractions and pinches of the chute or channel, with each other, and with the contact above. The general pitch of the ore channels is normal to their bedding plane, indicating their formation previous to the tilting of the limestone.

The contact deposits are more acid or siliceous than those in the body of the limestone, which are more basic, and composed largely of the oxides of iron and manganese, carrying a higher value in silver. The presence of gold also, if found at all, is greatest near the contact. The ore chutes on Iron Hill, are the North Iron chute, the South Iron chute, the Gold or Cord chute, the Ruby Channel chute, the Innes chute, the White Cap chute, the Smuggler chute, the Stone chute.

IRON CHUTES.

The Iron chute is a type of the contact deposits of the Leadville district. It has been worked at enormous profit by one immense continuous stope, from its stope at its junction with the Iron Hill for a distance of 1,500 feet easterly, and westerly of 900 feet. It is one homogeneous body of carbonate ore lying immediately under the white porphyry, and filling the shallow basin-like replacement of the blue limestone to an average depth of eight feet below the contact. Its width is about 350 feet, pinching up to tight-contact on its flanks. From the apex of the blue limestone, the North Iron chute, having been broken or faulted with the entire hill formation, is found again occupying the same horizon, the blue limestone, with a slight lateral movement to the north.

IRON FAULT.

The Iron Hill fault, with the westerly continuation of this chute, has been here thoroughly developed by the McKeon inclined shaft, which is sunk at an angle of 50 degrees, just east of the fault claimed, and near the bassit edges of the limestone. By westerly levels driven from this shaft, the fault is found to have a throw of 500 feet with an angle to the westward of 60 degrees, nearly perpendicular to the eastern dip of the upper strata. West of the fault the limestone is found dipping westerly, and breaking into consecutive minor faults or jointing planes, in the form of steps, which decrease and disappear in the bending and basining up of the limestone, and continue west into the easterly dipping beds of Carbonate Hill. The westward continuation of the chute is seen in the Star of the West mine, Satellite, etc. The ore bodies are best upon the surface of the limestone, and seldom on its bassit edges.

GOLD ORE CHUTE.

This chute is so named on account of the unvarying persistent presence of gold in all its ores. It is an instructive chute also on account of its extensive development of 2,500 feet. For its first 300 feet it occurs in two principal branches, in which the ore bodies are formed in most irregular but connected chambers or pockets, extending on the contact to a depth of 1,080 feet in the limestone, and probably entirely through it. Continued north-east the contact ore entirely disappears, and the chute becomes a net-work of crevices and channels of ore, and vein material, stands perpendicular to the strata of the limestone, and often enclosing blocks of partially replaced lime, sand and limestone, examples of the latter having been observed, in which the bedding planes as well as their proper horizons, were still in their relatively original positions, a conclusive evidence amongst many others against the theory of the ore deposits in pre-existing cavities. In one place the ore extends down into the limestone from the upper contact through narrow crevices.

STONE CHUTE.

The outcrop of this chute in the bed of California Gulch, led to the first discovery of carbonate ore in the Leadville mining district. In the occurrence of ore bodies in this chute, the limestone replacements is proximity to the eruptive rocks have been enormous, resulting in the largest deposits of ore yet discovered in Leadville, some of them upwards of one hundred feet in thickness. Near the surface the ore is a carbonate, but with depth consists of large bodies of iron sulphide, lead and zinc. Seventy-five per cent. of these sulphides is low grade, with some streaks of very high grade ore mixed with them. Neither the sulphides of iron, lead, or zinc seem to have exerted any special influence or affinity for the deposition of the silver. The richest values of the latter are found in the same ore body combined distinctively with a preponderance of fresh ore, and the other of the former sulphides.

The results of Mr. Blow's report point to the continuity of these great ore chutes beyond their present development and also to the probable existence of ore bodies on consecutive and lower horizons in the limestone underneath those already discovered and worked, and particularly upon the lower contact of the blue limestone with the gray porphyry.

REDCLIFF ORE DEPOSITS.

Redcliff mining camp is situated on the west bank of the Eagle river some thirty or forty miles north of Leadville. The general geology is very similar to that of Leadville, viz.: granite below, on that Cambrian quartzite, Silurian and Carboniferous limestone and Upper Carboniferous Weber grits traversed by eruptive porphyries. The camp is both a silver, lead and gold producing one. The greatest peculiarity is in the occurrence of the gold ore deposits.

Going down the valley of the Eagle river we enter a deep, narrow cañon and look up on lofty cliffs of granite rock surmounted on the top by battlements of Cambrian quartzites and other Paleozoic strata. This is Battle Mountain on which the principal mines are above the little town of Redcliff.

The gold ore deposits are confined to cavities in the cambrian quartzites, one of the few occurrences in Colorado where this intensely hard vitreous rock is productive to any extent of the precious metals. Above the quartzites are the silurian and carboniferous limestones, traversed by eruptive sheets in which occur the usual lead and silver deposits as at Leadville.

Mr. F. Guiterman, in the proceedings of the Scientific Society of Denver, gives an account of the peculiar ore deposits, from which we extract the following:

"The gold often occurs in nuggets. The quartzites dip 10 degrees to the north-east. Between these quartzites lies the ore. The contact between the layers of quartzite is sharply defined. The 'contact filling' is a breccia of fragments of quartzite cemented with iron oxide and at times with iron pyrites.

"This mineralized breccia is from six to four feet thick. The ore chimneys in this filling occur at intervals. Their presence is marked on the outcrop by what is called a 'joint clay,' an aluminous deposit on top of the ore body following it along the roof for about 200 feet, then gradually thinning out and disappearing entirely when the unaltered iron pyrites is reached.

"The 'ore chimneys' are four feet wide, the thickness being limited to the distance between the floor and roof. The quartzite roof is always smooth but the lower quartzite floor is quite rough and corrugated and shows chemical action upon it, attendant upon deposition of ore. The floor at times is impregnated with ore not extending any great distance into it. Though ore chimneys are six feet wide the pay ore is only a few inches, swelling from floor to roof. Pay ore in the oxidized portion yields seven ounces gold and fifty ounces silver. In mining, the floor is followed as a guide. Individual ore chimneys are connected laterally by ore chutes like a net-work. Ore chimneys divide and separate, the branches re-uniting or again splitting up. The whole ramification comes together again at intervals in one main chimney.

"The rock filling space where the divergence has taken place is the same as the 'breccia filling,' only more compact, impregnated with pyrite. These fillings are left standing as pillars after mining ore.

"The characteristics of the quartzite ore deposits are, first: The outcrop of an ore chimney with its joint clay. A zone of oxidation for 200 feet which gradually merges as the natural water level is approached through a zone of mixed oxides and sulphides to the zone of unaffected oxides or iron pyrites.

Second. The 'joint clay' gradually disappears as the sulphides of iron are approached. The silica contents of the ore in the zone of complete oxidation are 30 per cent. These lessen as the zone of unaltered pyrites is neared down to 21½ per cent. Sulphur is present in the oxidized zone, combined with oxygen as sulphuric acid which is united to sesquioxide of iron, forming crystalline minerals called copratite.

The analysis of the ore is

Hydrated sesquioxide of iron	54.30
Sesquisulphate of iron	12.00
Silica and alumina	31.20
Barium sulphate	2.70

"In the Ground Hog Mine the ore chimneys are 600 feet apart, but are probably connected. They abound in nuggets, some are isolated and twisted like bent horns, others in a different chute are lumpy. The lumps are composed of distinct crystalline particles cemented together by sesquisulphate of iron and horn silver. Gold nuggets are found in troughs on the quartzite floor imbedded in clay associated with rich silver ore or horn silver. With the nuggets are lumps of sesquioxide of iron carrying much gold.

"This proves that the secondary deposition of gold in crystals and nuggets was through the medium of persulphate of iron derived from slow oxidation of iron pyrites. The successive development of oxidized ore from a sulphide is thus shown. The sesquioxide of iron in the Ground Hog Mine is rich in gold, but so minutely disseminated that it will not even "pan." Lastly, the cementation of the nuggets by sesquisulphate of iron, all prove Le Conte's theory of the origin of our gold veins as stated in his Geology, Pages 247–248, New Edition"

GUNNISON COUNTY

Lies West of Chaffee county, its eastern boundary being partly formed by the crest of the Sawatch Range. It contains both a plateau and a mountain region. The former is occupied by horizontal Cretaceous and Tertiary strata.

Except where the Archæan granites are exposed by erosion or eruptive rocks have broken through the sedimentaries, there is not much prospect of the precious metals. Where, however, they do occur, vast bodies of coking, anthracite and semi-bituminous coals of the best quality are on hand for smelting purposes.

The region has heretofore been retarded by the lack of transportation facilities; now that requisite is fully supplied by the Rio Grande and Union Pacific railways.

The geology of the western slope of the Rocky Mountains proper differs somewhat from that of the eastern slope. In the latter region the strata rest usually in their natural consecutive order from Silurian to Tertiary upon the granite, the Silurian lying directly upon it as upon a shore-line.

In the western region and slope, the Cretaceous often lies directly upon the Archæan and the Silurian is not found, implying that a land area existed over this region, raised above the Silurian, Carboniferous, Triassic and Jurassic seas, which were depositing sediment along the eastern flanks, and it was not until the Cretaceous era that this western area, probably by subsidence, was covered by seawater and marine sediments.

The coal-forming period, which on the eastern flanks occurred near the close of the Cretaceous, appears to have occurred, on the western slope, at an earlier date in the same age.

The ore deposits which in the eastern division occur in the Archæan and Paleozoic formations, in the western occur in the Mesozoic rocks as late as the Cretaceous.

The general geological structure of the Elk Mountain region is that of a great "fault fold," an anticlinal fold or arch, running generally with the axis of the range, broken along its crest by a fault. The eastern slope of the fold is gentle, but the western is very steep, and even overturned or inverted.

The Carboniferous, Triassic and Jurassic have escaped erosion in the highest portion of the mountains, while the Cretaceous beds have been eroded away till they lie along the flanks.

In the center of this fold is a mass of eruptive quartz porphyry and diorite, which breaks through the sedimentaries not only in dykes, but also in immense masses forming entire mountains, of which White Rock (diorite), Crested Butte and Gothic Mountains of quartz porphyry are typical. Some of these suggest that they are remnants of laccolites, those reservoirs of molten rock from which the strata have been removed by erosion.

The date of these intrusive masses and eruptions is post Cretaceous, but their characteristics show them to be not of Tertiary type. The intrusion of these enormous masses of molten material, together with the mechanical heat engendered by the violent folding to which the region has been subjected, has produced a widespread metamorphism of the surrounding rocks, including the coal which is metamorphosed into anthracite. Some of the limestones are changed into white marble of superior quality. This metamorphism, combined with other phenomena has made the region peculiarly favorable for metallic veins.

These Elk Mountains are of later origin than the Sawatch range, and probably later than the Mosquito or Park range. They are apparently the youngest mountains in Colorado.

The ore deposits in the Ruby and Irwin districts are of Cretaceous age, as the vein and ore deposits traverse Upper Cretaceous rocks and penetrate the Cretaceous coal horizon.

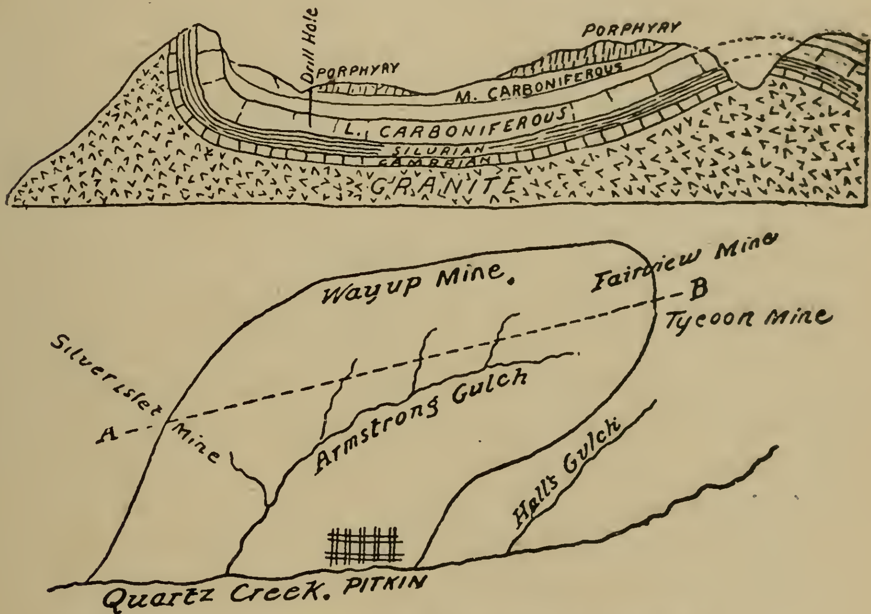
Ore occurs at a great many localities in the Elk Mountain region and on the flanks of the Sawatch.

The principal mining centers of the Elk Mountain region lie both in Pitkin and in Gunnison Counties, and are as below.

RECENT OBSERVATIONS AT PITKIN.

BY PROF. B. SADTLER.

Some recent observations and explorations by Prof. Benjamin Sadtler show that a large and important area around Pitkin will be available for ore production in the the future of which but little was suspected in the past.



Section and Plan of Pitkin District.

He says: "The recent record of diamond drill borings and other stratigraphical explorations in Pitkin and Gunnison counties show that Hayden's map marks as unprofitable granite, a large area overlain by Paleozoic strata more or less ore-bearing and profitable. Around

Armstrong Gulch, which joins Quartz creek at Pitkin, is a distinct horseshoe of Paleozoic strata of Cambrian, Silurian and Lower Carboniferous ages, with mineral-bearing contacts which have been mined at the surface for some time. Along the Southern rim the sedimentary strata crop out in a nearly vertical position. The mineral contacts of this have been found by the Silver Islet, Way-Up and other mines. Around the western and northern rims of this basin the croppings are not so sharply uplifted. This is especially the case on the north rim where the dip varies from 12 to 39 degrees. Along this rim have been found such large producing and shipping mines as the Fair-View, Cleopatra, Terrible, Little Tycoon, Hindoo and others. The upheaval along this side seems to have been due to a simple roll or fold in the stratified rocks along which erosion has produced Hall's Gulch. Beyond this gulch to the northward, the same sedimentary rocks with mineral contacts appear dipping northward and showing along the cropping such mines as the Silent Friend, Swiss Belle, Saint John, etc. Investigation has shown the probability of these sedimentary stratas in the center of the basin being reasonably near the surface, especially in Armstrong Gulch and its tributaries. At one place the diamond drill borings of the Silver Basin Company showed the upper or Tycoon contact to have been within 300 feet of the surface and to carry ore at that point. The stratigraphy of the district is as follows, beginning from the basal granite:

	FEET.
First, Granite	—
Second, Cambrian quartzite	100
Silurian siliceous limestone, with bands of quartzite	350
Parting quartzite	20
Lower carboniferous dolomite (20 per cent Mgo.)	30

FAIRVIEW CONTACT.

Shales, black, red and mottled	70
Limestone	50
Dolomite (19 per cent. magnesian oxide)	50
Limestone	70
Rusty limestone	234

TYCOON CONTACT.

Dolomitic limestone	104
Blue limestone	55
Shale	8
Intrusive porphyry 17 feet thick occurs here.	
Magnesian lime	103
Intrusive porphyry	163

Above this follow the Weber grits, showing a remnant about 100 feet thick, the rest having been removed by erosion. It will be observed that the mineral contacts are between sedimentary strata, not between porphyry and limestone, as at Leadville. The section is more like Aspen. Recent developments showing nearly the entire mineralized contacts to be accessible in the center of the basin as well as around the rim, vastly increase the possibilities of the district as a mineral producer and as a camp of the future.

Aspen, on the north-east slope of the Elk Mountains, in the interval between the Elk and Sawatch ranges.

Independence is on the west slope of the Sawatch range.

Ruby, Gothic and others, on the south-west slope of the Elk Mountains.

Pitkin and Tin-Cup, on the south-west slope of the Sawatch.

At Independence, sulphuret ores carrying silver and gold occur.

The "Gold-Cup" mine, near Alpine Pass at Tin-Cup, occurs in the Carboniferous limestone similar to that at Leadville. The ore is argentiferous carbonate of lead and oxide of copper.

At Irwin the "Forest Queen" occurs in a vein associated with a vertical porphyry dyke traversing the Cretaceous sandstones. The ore is ruby silver, arsenical pyrites and sulphurets of silver, occurring in small crevices and fissures in the decomposed porphyry. The gangue is an indistinctly banded quartz. Faults occur in the mine.

On Copper Creek, near Gothic, a series of nearly vertical fissure veins traverse the eruptive diorite rocks. These veins are mineral-bearing, and at the Sylvanite mine have produced a great deal of very rich ore. Among it are very large masses of sulphurets of silver and extraordinary specimens of native silver, in curly bunches resembling bunches of tow, in considerable quantities. Some of these silver curls are oxidized into a bright golden color.

PITKIN COUNTY.

THE ASPEN MINING REGION.

The ore deposits of Aspen occur in the same geological horizon as those of Leadville, viz.: The Lower Carboniferous, shown by the fact that the limestone enclosing the ore contains fossils similar to those found in the ore-bearing limestone of Leadville, as also by its position relative to the Cambrian quartzite and Archæan granite below, and the Carbonaceous shales and the Weber grits of the Middle Carboniferous above it.

Aspen Mountain is on the risen side of a great fault which is clearly seen on Castle Creek on its southern side,


Aspen Mountain and City
Viewed from
SMUGGLER HILL
GRANITE
CASTLE CREEK
MAROON CREEK
VALLEJO GULCH
SPAR GULCH
SCHILLER
ASPEN
EMMA
SPAR
PIONEER
PIONEER GULCH
VETERAN TUNNEL
ENTERPRISE
SLIDE
DRIFT AND SLIDE ROCK
CONTACT
JURASSIC
CRETACEOUS 1, DAKOTA GROUP
SNOW MASS MT
SOPRIS PK

PLATE XVI.

by which the Mesozoic red beds, and other groups, have fallen several thousand feet from their proper position above the Paleozoic series, which cap the summit and sides of the mountain in which the mines are principally located.

This faulting was due to the elevation of the Elk Mountains crushing the intervening sedimentary strata between them and the Sawatch range, into a series of folds which, when they had reached their greatest tension, broke into a series of faults. Besides the one great fault there were several minor faults attending this movement, which are found in various parts of the mountain and adjacent region. Some of these faults are more recent than the ore deposits, as they fault them slightly. Whatever motion is visible in the mines, such as slickensides and smooth walls, is to be attributed to these later movements rather than to the production of any fissure subsequently filled by the ore deposits. The ore appears to occur as a replacement of limestone, the lower portion of which is dolomitic in character, while the upper portion is true limestone. The ore replaces both forms of the limestone and penetrates its mass through various jointing planes spreading out at intervals between the planes of stratification in a more or less irregular way. The principal line of concentration appears to be at the point where the limestone becomes dolomitized.

Overlying the limestone, but separated from it by a thick bed of black argillaceous shale is an enormous mass of eruptive diorite, from which it seems probable that the ores were derived through the medium of percolating surface waters in a somewhat similar way to that at Leadville.

The ores are fine-grained galena, rich in silver. A good deal of silver sulphurets, polybasite, and decomposition products of these.

ABSTRACT OF PAPER ON THE ASPEN MINING REGION, BY S. F. EMMONS.

"The Aspen mining region is related to that of Leadville. Each is on the shore line of the old Archæan island of the Sawatch, one on the east, the other on the west, and opposite one another, (though about fifty miles apart.)

The ore deposits occur in the same general horizon as at Leadville, viz., the Lower Carboniferous limestone.

Both are regions of intense dynamic disturbances, which have been accompanied by immense intrusions of igneous rock through the sedimentary strata.

The process of ore deposition in either region has been an actual replacement of the country rock by vein material, and when open cavities occur they are found to be of later formation than the original deposition of ore.

At Aspen the ore is not found in actual contact with the eruptive bodies, as is generally the case at Leadville, and the country rock, instead of being entirely dolomite, is only partially so, and whereas at Leadville there is reason to assume that it was originally deposited as a dolomite, at Aspen there is some reason for thinking that the dolomitization may have been in part, at any rate, a secondary process, entirely subsequent to the deposition of the limestone."

"The mines of Aspen are situated in Paleozoic strata reclining upon the slope of a narrow ridged mountain forming a granite spur *en echelon* with the Sawatch Range.

The strip of country in the vicinity of Aspen constitutes the dividing line between the two distinct uplifts of the Sawatch Range on the east and of the Elk Mountains on the west, and has been affected successfully by the dynamic movements accompanying each upheaval.

The Sawatch upheaval was a gradual elevation of this mountain mass, resulting from a gradual subsidence of the adjoining sea bottoms, which caused the sedimentary beds deposited in those sea bottoms to slope up at varying angles all along the ancient shore line toward the central mass of the Archæan island.

The Elk Mountain Range, which extends to the west and south of this region, was upheaved later than the Sawatch, with greater violence and eruptive energy, and the upheaval was accompanied by enormous intrusions of eruptive rock which were forced into the sedimentary strata already shattered by the forces of upheaval, in great 'laccolites,' or solid masses, and spread out through them in every direction in the form of dykes and intrusive sheets. The surface exposures of these igneous bodies cover areas of twenty-five to thirty square miles, and their extension below the surface is doubtless very much greater.

The intrusion of such enormous masses of foreign matter must not only have greatly disturbed the beds within the region of upheaval, but also have so expanded the volume of the earth's crust in this area as to cause a severe lateral pressure in the adjoining region. That adjoining region was Aspen and its neighborhood.

It would be just in the strip of sedimentary beds along the Aspen Mountain ridge, which is backed by a projecting point of the unyielding Sawatch Archæan that this compression would be most severely felt, the Sawatch granite mass acting as a point of resistance against the intense lateral compression caused by the younger Elk Mountain uplift.

The sedimentary beds resting against the Archæan correspond generally, with slight differences, to those in the South Park and Leadville region in a similar position.

STRATIGRAPHY OF ASPEN.

The latter were deposited in a partially enclosed bay, now constituting the South Park basin, the former on the west side of the Archæan island in a wider and deeper sea, and on this western slope the beds are generally much thicker than those of corresponding geological horizons on the East.

1. The horizons represented are the Upper Cambrian quartzites, 200 feet, resting on the Archæan granite.

2. Silurian silicious limestones and quartzites, 340 feet.

3. Darker limestones, rusty brown and dolomitic at base, blue, compact and pure on top, 240. (These are Lower Carboniferous.)

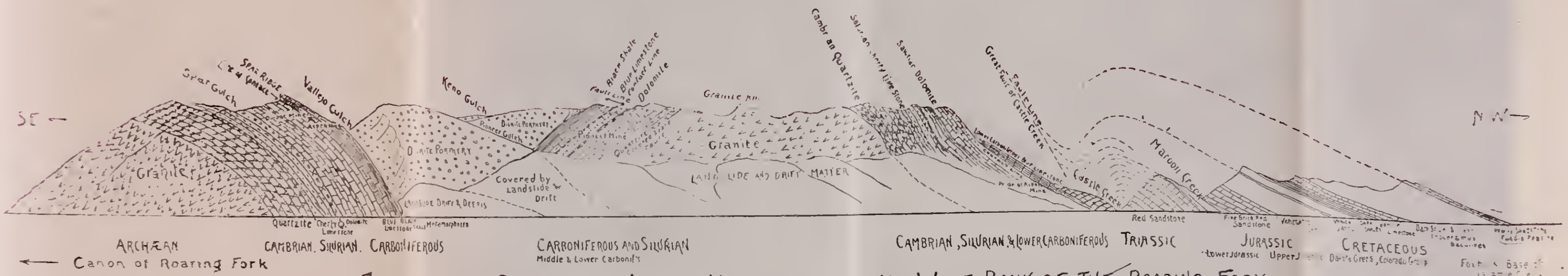
4. Carboniferous clays and shales and thin bedded limestones, 425 feet. These belong to the Weber grits (Middle Carboniferous).

5. A series of variegated green and red sandstones, clays and shales, some limestones and red sandstones of the Upper Carboniferous.

6. Heavy bedded red sandstones (Triassic).

Above these again are several thousand feet of Cretaceous strata, up to the base of the Laramie coal beds. (The Cretaceous, however, and the Jurassic do not rest immediately in any case upon the granite).

Diorite. On Aspen Mountain is a bed of white porphyry (diorite) in the black shales, 60 to 100 feet above



GENERALISED SECTION OF ASPEN MOUNTAIN AND THE WEST BANK OF THE ROARING FORK

PLATE XVII.

the top of the blue limestone. It is 260 feet thick on the slope back of town, but thickens considerably to the south, and is traceable to Ashcroft." [It appears to extend also across the valley of Roaring Fork to Smuggler Mountain. Small intrusive sheets also occur in the lower quartzites near the point of Aspen Mountain and on the east face of Richmond Hill.]

"As affected by the Sawatch upheaval, these beds wrap around the Archæan mass resting against or dipping away from it at varying angles.

The quartzites and limestones cross the valley of Roaring Fork from Smuggler Mountain to Aspen Mountain, striking north-east and south-west, dipping north-west. The angle of dip is about 45°, varying from a minimum of 30° to a maximum of 60° in 'flats' and 'steeps.'

At the upper end of Spar Ridge, blue limestones change in strike from north-east to north, bending to the south till they reach Ashcroft, the westward dip shallowing nearly to a horizontal at the head of Spar Gulch and steepening again to 45° near Ashcroft.

In the hills forming the east bank of Roaring Fork valley, from Smuggler Mountain north-westward is a continuous conformable series of beds from Cambrian to Cretaceous dipping north-west. Were this region affected by the Sawatch upheaval alone, we should expect to find this same series sweeping continuously around and resting conformably upon the flanks of the lower Paleozoic strata which form the crest of the ridge from Aspen to Ashcroft. Instead of this, on the steep west slope of Aspen Mountain, towards Castle Creek, we find, now the blue limestone, now the Cambrian quartzite and again the Archæan granite, abutting against the Triassic beds, and going northward along the east slope of the mountain back of Aspen City, after passing geologically upwards through blue limestone, black shales, porphyry and black shales again, we find the series repeated at the point of the ridge from granite up to blue limestone again, the latter beds lying in great slabs against its northern ends, striking east and dipping about 60° to the north.

This is the result not of mere folding but of extreme compression resulting in faulting.

There is not only one great fault, but several smaller parallel ones. This compression proceeded from the upheaval of the Elk Mountains crowding the sedimentary beds against the unyielding Sawatch Archæan mass, so that along its edge they have been broken across and shoved up past each other.

CASTLE CREEK FAULT.

The line of the principal fault is shown by its movement bringing the red sandstones in juxtaposition to the limestones, quartzites and Archæan rocks on the east. The minor faults are more obscured by *debris*. The main fault is visible around the point of Aspen Mountain, where Castle Creek cuts into its northern foot. Vertical red sandstones striking north and south appear parallel to the fault plane. These adjoin the steeply upturned quartzites which strike east and west across the northern end of the ridge. The fault runs for several miles southward along the foot of the hill, parallel with the bed of the creek, gradually rising higher on the slope. On the west side of the fault the Red beds stand either vertical or dipping slightly eastward.

In the hills on the west side of Castle Creek the same beds are nearly horizontal, or dip 10° to 20° to the north down the creek. The beds exposed are successively lower as we ascend the creek. At Queen Gulch there is a decided dip eastward of the red beds 15° from a vertical. To connect the vertical beds with the horizontal on the opposite side of the creek would involve an S shaped synclinal. Such a fold is evidence of intense compression accompanying the faulting, sufficient to double together these heavy sandstones as closely as one folds sheets of paper. Queens Butte, about two miles below Aspen, is a good example of this overturned S fold, the Jurassic beds lying on top of the overturned Cretaceous.

This butte is on the same line of fault and marks its continuation in that direction.

In Ophir Gulch the line of the fault is well marked by an outcrop of granite in the bed of the gulch adjoining the sharply upturned red sandstones. A tunnel has been run in on it, and the fault plane of the granite wall dips 45° to the east.

The fault there is a reversed fault, because the upward movement was in the hanging wall contrary to the usual law of faults by which the foot-wall rises. The plane of the Castle Creek fault has an eastward dip, instead of a westward one, implied also by the fact of the beds immediately adjoining the fault on the west often dipping east also.

Beds west of the faults were more plastic than the older ones now adjoining it on the east. The former not being fractured, the latter being broken by many minor faults parallel to the main fault with no evidence of such closely compressed folding as exists in the former.

In Queen's Gulch white quartzite is the first outcrop east of the fault, then overlying brown limestone, a gap, and then quartzite dipping 45° west, granite below them in tunnel. One thousand feet above this are the Queen's

Cliff outcrops of blue limestone and brown limestone forming the southern point of Aspen Mountain.

On the ridge running west from Queen's Cliff between Ophir and Queen's Gulches are three minor faults west of the main fault. One mine shaft here had a limestone east wall and a red sandstone west wall. Another had limestone one side and granite the other. The latter had crossed the fault line and was drifting hopelessly into the Archæan mass.

On the summit of Queen's Gulch at Queen's Cliff is an exposure of several hundred feet of blue and brown limestone dipping 15° west. On the ridge, east of this, across the head of Spar Gulch on Ajax Hill the same series is repeated, separated by a slight fault on the line of Spar Gulch. Following down the east slope of this hill we cross successively the lower limestones and Cambrian quartzites striking north and south dipping gently west, and found resting upon the Archæan at the base of the first steep slope of the ridge, 500 feet below the summit.

NORTHERN PORTION OF ASPEN MOUNTAIN.

For some distance north of Queen's Cliff limestone is the cap rock of the ridge, the overlying porphyry having been eroded off. On the round-topped hill at the head of Ophir Gulch on whose east face is the "Campbird" mine, several hundred feet of porphyry overlie the limestone.

Its sudden appearance is accounted for by a fault crossing its southern end running west of north with upthrow on the south. Northward from here as far as the head of Keno Gulch porphyry forms the whole upper portion of the ridge. Below it along the west wall of

Spar Gulch the limestones and their ore-bearing zone are traced by occasional out-crops, and by the workings of many mines.

The line between porphyry and limestone descends to the north till the change of the strike from north to north-east comes in, where the bend causes a steepening of the strata.

The blue limestone of Spar Ridge runs diagonally across the course of Spar Gulch, closing it into a very narrow ravine in its lower portion, and finally crossing it at the bottom, passes over the poiut of the main ridge to the east of it, to disappear beneath the valley of Roaring Fork.

The overlying porphyry also bends around the north-east conformably and forms the ridge bounding Vallejo Gulch on the north, on the sloping crest of which several shafts have been sunk.

To the north, beneath the surface, on the east slopes of Aspen Mountain, several hundred feet of dark limestones and carbonaceous shales rest conformably on the porphyry sheet though near the surface they have been eroded off.

The beds follow normally the outline of the Archæan, not broken by any serious faults.

Minor faults following the direction of the Castle Creek fault will be found like that which runs across Spar ridge above the Durant cliff, extending across the Bonny-Bell ground on the south and the Aspen on the north.

From the head of Keno Gulch north, the ridge of Aspen Mountain is set off *en echelon* to the west of the main ridge, as the whole body of the mountain is set off from the main ridge at Queen's Cliff. The highest and most southern point of this ridge overlooking the head of Keno Gulch, ("Acquisition Hill") is separated from the main ridge by a V-shaped depression running north and south.

Brown limestone, granite and white quartzite appear, the former at the southern end and running along the eastern face in a northerly direction. Granite adjoins it on the west and the quartzite rests on granite on the north and west.

Faulting has brought the limestone and granite into juxtaposition. The fault plane is cut in the Acquisition mine, whose tunnel passes from the brown limestone into granite at 300 feet. Following the ridge north, beds of limestone and quartzite appear striking north and south, with steep dips. About half way to the north point granite comes in, forming the crest of the ridge as far as where the successive great slab-like masses of quartzite and limestone rest against it, and dipping steeply north, form the extreme point of the mountain.

On the south and east of this mass of granite, the beds are broken by a series of minor faults, running north and south. Near the Pioneer, in some tunnels, vertical faults and slip planes running north and south occur, the striations indicating an upward and downward movement at an angle of 60° to the horizon, towards the north, or in a reversed direction downward 60° towards the south. The beds north of the granite have an east and west strike, but tend to wrap around the granite body, as in the east they curve in strike to the southward.

The structure of this ridge is as follows: By the movement of Castle Creek fault this body of granite and the strata resting on its north side were dragged bodily upwards from their normal position on the downward dip of the beds out-cropping in Spar Gulch, and with a relatively greater movement of displacement than the rest of the region, since they must have been lower down originally.

The upward movement was relatively greater immediately adjoining the fault than at some little distance to the east, and thus the west end of these uplifted beds was carried further upward and northward than the east end. Their strike was shifted from north-east to east and a little south of east.

In the intermediate region to the south-east between the granite beds and the normally dipping beds of Vallejo Gulch, which is farther away from the fault plane, the beds were dragged up on the flanks of this upward moving granite body, not in a single mass like the strata to the north, but holding back as it were, sloping up against it at steep angles, and slipping back along minor fault planes.

As the limestone on the steep side by the Pioneer Mine dip east, an anticlinal fold over the granite, and a synclinal fold or basin between it and Vallejo Gulch has been assumed to exist. There may have been an abortive attempt to form such folds, but the space was too limited for their free development and they were fractured before the folding was completed. There are no continuous unbroken curves representing folds except perhaps in the re-entering angle of the hill formed by the upper part of Pioneer Gulch.

The New York tunnel, 1,000 feet above the town, runs 1,100 feet into the hill in a direction south 20° west. It crosses the strata at right angles.

These have a north-westerly instead of a north-easterly strike. It passes through 100 feet wash, 585 feet conformable limestone, shales and included porphyry, before reaching the top of the blue limestone.

It is possible, though improbable, that a horizontal drift running south-east along a given bed, such as the blue limestone, would make a continuous curve to the north-east unbroken by a fault before reaching the outcrop of the Spar Gulch, and so prove the existence of a synclinal basin under the northern portion of the porphyry. Of continuous folds north of this, there is no possibility, and while the Spar Ridge limestone stretches across Roaring Fork Valley to Smuggler Hill, and ore bodies may be found beneath the valley, the same continuity cannot be expected in the limestone beds of the northern point of the mountain. The beds in a corresponding position to them on the east side of the valley belong to a higher geological horizon, hence somewhere in the valley between they must be cut off by faults, probably nearer to Aspen Mountain than to the other side of the valley.

ORE-BEARING HORIZON SUPPOSED TO BE AT CONTACT OF BLUE LIMESTONE AND UNDERLYING DOLOMITE OR BROWN LIMESTONE.

The blue limestone is compact, homogeneous and pure carbonate of lime. When crystalline its crystals are larger than those of the dolomite. The brown limestone, when unaltered, is of a dark blue gray, finely crystalline, finely granulated, and traversed in every direction by a net-work of minute veins containing iron salts which when oxidized color the surface a rusty brown.

The oxidization along these minute veins makes it break easily into dice-shaped fragments giving the rock a "crackly" structure, hence its name of "short lime." The rock has not been crushed or brecciated, it is a true dolomite.

The thickness of the blue limestone is from 120 to 150 feet.

On the cliff on Spar ridge above the Durant Mine, six lenticular seams of dolomite are included in the blue limestone, weathering more rapidly than the blue, they produce indentations in the cliff.

On Smuggler Mountain the presence of the blue limestone is not clear. It is doubtful if the "contact" is one and the same geological horizon throughout the region.

From a few fossils and lithological structure, both blue and brown limestone belong to the same horizon, the Lower Carboniferous. The ore was not deposited in a fissure formed by the movement of the blue limestone over the brown dolomite, if it had been, striated surfaces and crushed material would be found.

This would happen if these solutions derived their metals from the overlying porphyry, for it is separated from the limestone by argillaceous shales which would be impervious unless fractured across the bedding. The analysis of the lime mud at the bottom of the cave shows by its preponderance of alkalies, which do not exist in the composition of either brown or blue limestone, that the waters dissolving it came from the porphyry. The waters brought both alkalies and silica from the porphyry, and probably the iron and baryta.

DOLOMITIZATION.

This is a secondary process upon the blue limestone by magnesian waters, which is proved by irregular tongues of dolomite extending up into and across the blue limestone. The lenticular bodies in the Durant cliff point to the same fact. The crackly structure of the brown lime results from the replacement of a molecule of lime by a molecule of magnesia, involving also a contraction in volume of the rock itself, which would cause it to separate in angular fragments, the intersections filled by material more soluble than the rock itself.

The magnesian waters may have been connected with those which brought in the vein materials.

In the ore bodies the partially mineralized rock on the borders of the ore is changed to dolomite, hence dolomitization either preceded or accompanied ore deposition.

Mr. Emmons suggests as *probabilitics* only, that the porphyry intrusion preceded the faulting.

That the ore deposits followed the intrusion of porphyry and also the principal faulting movements.

That small movements have taken place in recent times both in the strata and contained ore bodies since the oxidation of the latter. That at the time of the great faulting, the beds may not have attained entirely the present condition.

THE SAN JUAN REGION.

This region, which embraces the San Juan, Hinsdale, Ouray, La Plata, and part of Rio Grande and Conejos Counties, takes its name from the San Juan Mountains, a lofty, irregular mountain mass of a north-west trend, composed almost entirely of prodigious flows of lava, emanating in all probability from a series of dykes concealed underneath the flows. These horizontal flows have buried under their mass the primitive granite which is occasionally to be found peeping out from underneath it at the bottom of the profound cañons, from whose depths you can look up at a vertical section of from 2,000 to 3,000 feet of lava lying layer upon layer of different colors.

Some of these eruptive rocks consist of enormous thicknesses of volcanic "breccia" or conglomerate, which have a leadish gray appearance at a distance, but on nearer inspection the fragments composing them partake of an olive green or lilac color. There appear to be two sets of these eruptive rocks, one of older date than the other. The breccias belonging to a porphyritic or dioritic type are locally penetrated by dykes or covered by flows of newer eruptions, such as rhyolites, andesites and basalts. While some are Tertiary eruptives, others are of older date, and it is in these latter, particularly in the breccias, that the mineral veins more especially occur.

In certain portions of this region, besides the granite, sedimentary rocks of Carboniferous age, such as limestones and quartzites, and red sandstones of Triassic age, appear from under the prodigious lava covering.

They are generally more or less uplifted, while the lavas rest upon them horizontally. It is apparent then, that the eruptions occurred after the Triassic, and also after the underlying strata had been uplifted into something like mountain forms.

At the head of Uncompahgre River, near Ouray, Paleozoic limestones and quartzites, Triassic red sandstones, rest on the granite, and dip to the north-west under the Cretaceous formations covering the counties of Ouray and La Plata, which belong to the Colorado plateau region. In the southern part of San Juan County the same feature is observed.

Ore Deposits.—Probably few regions in the world are traversed by so many and such large veins. Immense vertical veins of a hard bluish quartz traverse the eruptive rocks. Their outcrops project like walls from the surface, or run down either side of the profound cañons for several thousands of feet, and though they penetrate both older and younger eruptive sheets, the ore bodies are most productive in the older eruptions, especially the brecciated rocks. Veins also occur in the underlying granite and gneiss.

At Rico, deposits occur between the bedding planes of Carboniferous limestones at contact with sheets of intrusive igneous rocks. The deposits are mainly argentiferous. Both gold and silver, however, occur in the lodes. Rich gold placer deposits are found near San Miguel.

The minerals are principally argentiferous galena, gray copper and bismuthinite, with ruby silver, native silver and zinc-blende. Molybdenite is not uncommon. Barite sometimes forms the gangue in place of the hard chalcedonic quartz. The veins often have a banded structure, and sometimes a brecciated one. In many cases one or both walls are not clearly defined, and a portion of the vein material is decomposed country rock.

There are two sets of veins traversing the region, one having a north-west by south-east, the other a north-east by south-west direction, thus cutting one another diagonally. The north-west is the commoner in direction.

Ore Occurrence of Red Mountain District.

SAN JUAN.

BY T. E. SCHWARTZ.

In the lowest level of the Yankee Girl mine at 90 feet below the surface, what was supposed to be the foot-wall of the vein, led Mr. Schwartz to the opinion that the ore deposit was a peculiar one and that the so-called wall did not bound a true fissure vein. A depth of 800 feet confirmed his suspicions and showed that the Red Mountain mines such as the Jedd, National Belle and others were peculiar in this respect.

He thinks the district was the scene of ancient mineral spring activity, that its ores now filled such water channels forming a section abounding in ore chimneys of irregular occurrence, probably great vertical depth and of small horizontal section.

The Red Mountain district occupies the basin at the head waters of Red creek from Ironton Park to the Divide, a distance of six miles.

The formation on the two sides of Red creek are very dissimilar. On the east side upon which are the mines, the Red Mountain presents a very rough exterior with jagged cavernous cliffs, long stretches of slide rock and bright red colors. A series of benches are also noticeable on this side. They form the base of the mountain to a height of 400 to 800 feet, characterized by quartz outcrops. At the south end of the district two small parks occur nearly surrounded by these massive outcrops, marking the location of many of the producing mines. These outcrops form knolls rising 200 feet above the surrounding surface. Many present a pyramidal appearance with a cliff of hard blackened cavernous quartz for apex.

The west side of Red Mountain Creek has slaty colored cliffs and no bright red or heavy outcrops.

The formation along Red Creek, east side, of some fifteen miles square, embracing the most productive portion of the San Juan, is entirely covered by an overflow of eruptive rock, rhyolite and andesitic breccias, in which most of the fissure veins occur of great strength and persistence, such as the Sheridan, Mendota, Old Lout, North Star, and others. These properties are dissimilar from those of Red Mountain.

The Red Mountain District has been the scene of intense metamorphism. The andesite is bleached over large areas full of Kaolin and breccia and pyrite. The white soft rock, with Kaolin faces encloses most of the Red Mountain ores. Massive knolls of quartz or silicified andesite occur. These in the National Belle and other mines are penetrated by caves and irregular passages, sometimes forty by sixty feet, filled with iron oxides, white Kaolin and ores of secondary deposition. These caves branch out extensively toward the surface, form large chambers and come together and diminish in size in depth. Evidences of their formation along certain cleavage and fracture planes affording passage for surface waters is often present. They extend in depth to the water level, which is nearly two hundred feet below the outcrop. These walls are smooth and rounded, sometimes hard, but generally of porous siliceous soft rock.

The ores of the district are of two classes: 1, Surface ores, or those of a secondary formation. 2, Sulphide ores, or those occurring below the former water level.

1. The ores of the first class are found in caves, either adhering to the walls on masses of stalactites or else as loose sand carbonates or a clayey mixture with Kaolin, heavy spar, and detached masses of ore and rock filling the caves to a greater or less extent.

The ore of the National Belle, Vanderbilt, and Grand Prize carry a heavy per cent. of lead, from 30 to 50 per cent. on carload lots. They occur as sulphides on coarse crystalline masses attached to cave walls or altered to massive sulphate or carbonate with the sulphide only as a central core. With these are lead arsenites, limonite and zinc-blende with considerable kaolinite. The latter occurs snow white, each grain being a perfect crystal. The zinc-blende in the National Belle is in rare form as botryoidal masses of nearly concentric fibrous layers, usually found detached from cave walls and lying in a mass of Kaolin on the bottom or side of caves. They are sometimes a foot in diameter. Adjoining caves vary considerably in the gold and silver contained in their ores whilst the coarse cube galena is usually lowest, and the dark carbonates the highest grade ore.

To the east of the National Belle lie a group of mines very similar to this character but differing in the presence of considerable sulphide and oxide of bismuth in the cave ores. This ore in the Enterprise carries 25 per cent. to 30 per cent. bismuth from which has been reduced several hundred pounds of metal 98 per cent. fine. The first large lot of metallic bismuth reduced on this continent.

The ores of the second class make the bulk of the Red Mountain production. In properties producing the oxidized ores, peculiar to caves, the unoxidized ores begin at water level where the cave ores cease. In other properties in which the cave formation is not present the latter class of ores outcrop on the surface. There the quartz knolls do not occur. These ores are sulphides and sulpharsenides producing galena, copper and iron pyrites, erubescite copper, bismuthinite, enargite, tetrahedrite, etc. Associated with these ores are rhodonite (silicate of manganese), gypsum and heavy spar or baryta.

In the National Belle, Enterprise, Hudson, in the upper and southern portion enargite occurs massive, and is the prevailing mineral below the horizon of oxidation varying greatly in silver contents from 15 ounces to 150 ounces per ton, associated with low grade iron pyrite and zinc-blende, with lead or bismuth sulphide.

In the northern or lower portion of the district are the two heaviest producing properties, the Yankee Girl and Silver Bell, near to the Guston, Paymaster and Genesee. High grade ores of Silver Bell are characterized by bismuth whilst in those of the Yankee Girl stromegerite (sulphide of copper and silver) is the principal minerals. The surface ores of the chimneys in this portion of the district are either galena or pyrite or copper pyrite. The change in character and grade of ores is sometimes rapid. Particularly in following the ore chimneys in depth owing to their sudden and irregular changes of pitch.

The prominent features of their occurrence are as follows:

1. The ores occur in chimneys with small horizontal section more or less circular and not more than 60 feet in diameter.

2. These chimneys consist of ore and its matrix, usually a hard fine-grained brown or grayish quartz, often

very porous. The ore is concentrated in one portion of the chimney, or embraces the whole of it, occurring massive and quite free from gangue for considerable distances.

3. The rock enclosing the chimneys is soft white andesite, occupying large areas, separated from each other by hard fine-grained blue-green "blocky" Diorite; the latter destitute of ore.

4. Individual chimneys, occurring in ore, are of "white rock," show no relation to each other beyond sometimes a similarity of ores or a gradual drawing together in depth.

5. Chimneys separated by areas of diorite are foreign to each other and show dissimilar ores.

6. The change from "white rock" to dionite has no regular course.

7. Ore chimneys often change their pitch quite suddenly.

8. Every chimney is connected with one or more cleavage or fracture planes, generally vertical.

9. Changes in direction or pitch, accompany an enlargement of the chimney.

10. The alteration of the enclosing rock increases as the ore-chimney is approached, more silver occurs, and cleavage faces with large or small masses of Kaolin. Notable instances occur of marked increase in grade of ore from the surface to considerable depth. In the caves the reverse often happens. Ores in the caves are richer than the unoxidized ores immediately below them. The mines by no means grow richer with depth. Copper and bismuth are the main enriching elements, and iron and lead the poorer. Car loads from Yankee Girl return at times 3,500 ounces silver to ton, with 30 per cent. copper. Silver Bell produced in large lots, bismuth ores, milling

500 to 1,000 ounces in silver per ton. The bulk of the Red Mountain ores at present, coming from a depth of 200 feet, carry 5 per cent. to 20 per cent. of copper.

It is evident the district has been one of great activity of heated mineral solutions, which have deposited their contents along nearly vertical channels and that such channels have been formed along planes produced by cooling of heated rock masses or by some near dynamic movement. Owing to the structure of the rock with its net-work of planes the circulation of these solutions must have been comparatively rapid. The strong horizontal planes which formed drainage courses for large areas collecting their mineral contents or solution might be expected to play an important part in determining the character of the ores in the chimneys with which they are connected. It seems that the alteration of the country rock and the deposition of the ores was simultaneous process. The general merging of ore into rock on one or more sides of the chimneys and gradual change of the hard quartz into soft andesite, together with the presence of kaolin in and adjoining the ore would indicate this. The absence of extended fractures of the formation having considerable lateral persistence accounts for the non-formation of fissure veins. The nature of the rock and the forces governing the subterranean circulation of mineral solutions favored their concentration at points of least resistance along vertical planes. In their passage upwards a gradual deposition of mineral contents and a replacement of portions of the adjoining rocks took place, forming chimney-shaped deposits, lacking in the confining walls and resulting regularity of fissure veins. The carbonate ores result from action of surface waters upon original sulphides changed to pyrite, galena, etc.,

SKETCH OF RICO, NEWMAN-HILL & DOLORES MT.

SKETCH OF NICO. NEWMAN-HILL & DOLORES MT.

found below, concentrating the silver and lead, other constituents being carried off in solution. The oxidized and dissolving properties of these surface waters account for the formation of caves along cleavage and fracture planes and the re-deposition of ores upon their walls.

RICO MINING CAMP.

SAN JUAN.

This camp is not very far from Telluride. Its general geological features are somewhat similar, but the ore deposits and their mode of occurrence is peculiar. A description by Mr. J. B. Farish, of the ore deposits of Newman Hill, will give the best idea:

"Rico is on the East Fork of the Dolores River, twelve miles from its source is the San Miguel Mountains. In the neighborhood of the town, sedimentary beds are found from the Lower Carboniferous to the top of the Colorado Cretaceous.

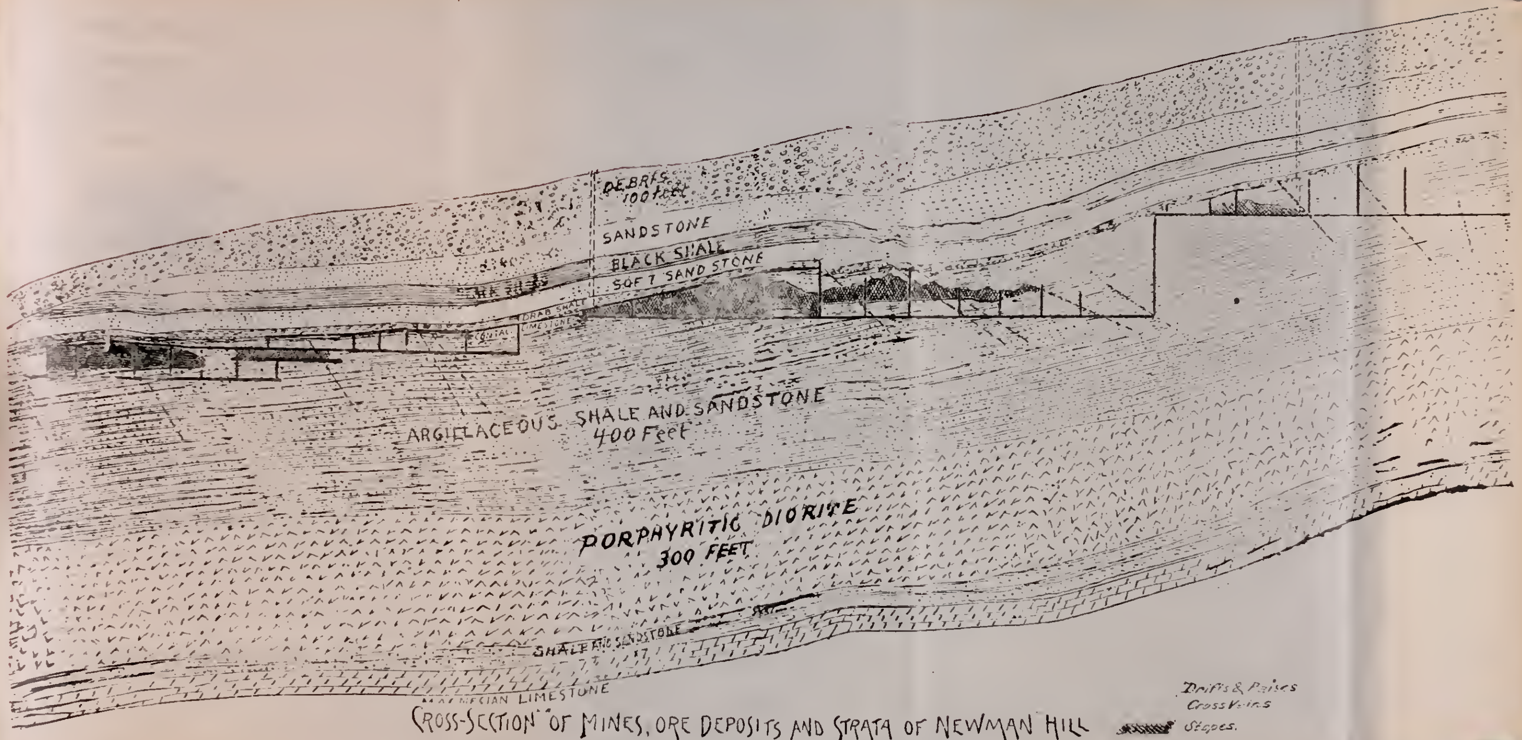
"The elevation of the mountains was associated in its origin with the upheaval of a great Diorite laccolite, from which the strata dip off in all directions up to 25°. The mountain is much faulted. Ore bodies occur mostly in the Carboniferous series, on both sides of the river.

Newman Hill forms a bench-like extension of Dolores Mountain. The lowest exposures at the foot of the hill on the banks of the river consist of a stratum of magnesian limestone, impregnated with chloritic matter. In this are large bodies of ore, principally iron and copper pyrites, and zinc-blende running low in silver. It is difficult to mine here on account of carbonic acid gas rising from circulating subterranean carbonated waters, which, when reaching the surface form soda springs. The limestone is charged with free gas. Shallow openings are quickly filled, and birds and animals venturing into them perish. The gas permeates the overlying strata, also vitiating the air in the upper mine workings.

On this limestone are alternate strata of sandstones and shales for a thickness of 500 feet, followed again by a band of limestone, and that by more shales. The total thickness of the section is about one thousand feet. The shales below the lime belt are harder than above it.

Fifty feet above the magnesian limestone a tongue or intrusion from the laccolite intrudes between the shales and sandstones. It is about 250 feet thick. This intrusion of porphyry is connected with the origin of the ore deposits, for the rock itself is sometimes replaced by pyrites. The rock is a porphyritic diorite or porphyrite consisting of hornblende, augite and feldspar.

The limestone belt midway up the hill called "contact limestone" is from eighteen to thirty inches thick. It is enclosed between beds of shale. The upper shales are soft and drab color and from six to twenty feet thick, forming an impervious shed to waters circulating above it. The underlying shale is black and about twelve feet thick, resting on sandstones and shales. The top of the bench is covered 300 feet with *debris*. The cliffs rising above the summit of the Newman Hill bench being part of Dolores Mountain are alternate bands of limestone, shale, conglomerate, and sandstone, followed above by the characteristic red and variegated strata of the Jura-Trias and these again by the shales, limestones, etc., of the Cretaceous. The average dip or inclination of the strata on Newman Hill is about 15 degrees south-east.

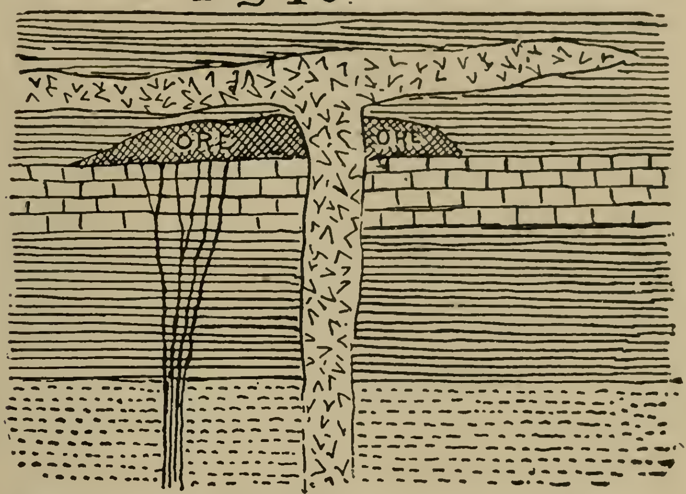


CROSS-SECTION OF MINES, ORE DEPOSITS AND STRATA OF NEWMAN HILL

PLATE XIX.

Ore deposits occur: 1st, on vertical fissures; 2nd, on another series of fissures whose inclination is about 45 degrees, crossing the vertical fissures at various angles; 3rd, along a horizontal contact plane between the so-called "contact" lime and the overlying shales.

Fig. 10.



Feeding Veins Dike and intrusive sheet.

The "vertical fissures" are the richest in ore and are locally called "vertical pay veins." The "cross vein fissures" have less ore and are lower grade. Both systems of veins are in fault fissures or fissures produced by movements of the rocks accompanied by fracture slipping and faulting, the amount of slip or displacement is about 25 feet. The fissures vary in width from a few inches to several feet. The veins show all the true characteristics of fissure veins such as "slickensided" or polished walls, gouge, and a ribbon or banded arrangement of the vein material.

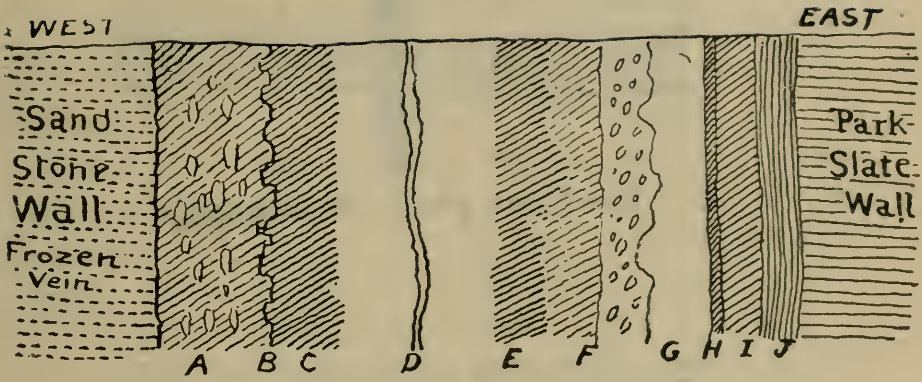
Longitudinally in extent the fissures show great strength, some of the vertical ones can be followed for upwards of 4,000 feet. Twelve vertical fissure veins have so far been opened. Some are almost barren, others are high grade, some are too narrow to work and others disappear or unite with larger veins.

There are five principal veins, the Swansea, Enterprise, Hiawatha, Jumbo, Eureka. The lowest workings are in the Enterprise, 200 feet below the "contact limestone." The veins are strong and regular till the black shale is traversed by them, when they split up into veinlets on shale and lime replacing the latter at times with ore until the overlying bed of shales is reached. The greatest deposit is on the contact plane by horizontal ore bodies in the form of a "pipe," varying from two to twenty feet in thickness. These "pipes" lie directly over the vertical fissures. The fissure veins do not extend beyond the "contact limestone." The fault fissures doubtless extend however above the "contact lime" but they are so tight that they can not be discerned. There is a close relation between the contact "ore pipes" and the underlying fissure veins, where the latter narrow, the the ore pipes also narrow. The cross veins are narrower than the verticals and their displacement is less.

The "cross veins" also separate and split up into veinlets on entering the shale below the "contact line." The ore pipes do not cover them, but make to one side of them. Horizontal ore bodies connected with these leading "cross veins" are from twenty to forty feet wide and from a few inches to three feet thick.

Where the "cross veins" join or pass the "vertical veins" they always disturb the latter.

The vein filling or gangue of the vertical fissures is a glassy white quartz, with vughs or crystalline cavities. The ore is pyrite, both copper and iron pyrites. Rhodo-



A 2½—*Rhodocrosite, with nodules and fragments of semi-crystalline quartz and small particles of blende and pyrites.*

B ½—*Gray quartz in irregular seam.*

C 1¼—*Coarse crystallized Sphalerite, with occasional cubes of galena.*

D 3½—*Semi-crystalline quartz, with a line of cavities along the center, lined with quartz crystals.*

E 1—*Sphalerites, same as last.*

F 2½—*Rhodocrosite, with line of quartz through center. Each half contains fragments of quartz, with some sphalerites and pyrites in small crystals.*

G 1½—*Quartz, mottled white and gray, with streaks of dark stain carrying pyrite, galena and sphalerite in crystals.*

H ¼—*Slaty matter, with very thin seams of quartz.*

I ¾—*Rhodocrosite and quartz, mixed with a line of pyrite crystals along the center.*

J 1—*Slate, clay, gouge or selvage.*

crosite or pink, carbonate of manganese, appears in the upper part, then zinc-blende, galena and gray copper ap pear. Continuing upwards the ore increases, also the gold and silver contents. Argentite, polybasite and stephanite or brittle silver occur in vein centers, together with horn silver and native silver. The limestone is often well replaced with ore. The "contact" ore is a solid mass of pyrites, galena, zinc-blende and gray copper, The silver contents are from 300 to 800 ounces per ton, and the gold two to nine ounces. The deposits are very uniform. The gold and silver of the cross-veins is only $12 per ton.

The "cross-vein" matrix is white quartz, enclosing portions of altered country rock. The dip of these veins being nearly flat, a greater fracturing of the shales and sandstones of the hanging-wall took place, allowing solutions to circulate freely, and enclose pieces of wall rock.

A number of fissure veins are said to occur in Dolores Mountain above Newman Hill, showing the faulting extended through the mountain. Their limitation to the "contact zone" is thus explained. After the fault fissures later movements closed the fissures in the soft argillaceous shales overlying the "contact limestone" preventing circulation upwards. The ores of the main laccolite are pyritiferous. Those of Rico District carbonate of lead and iron oxide.

Gold Ore Deposits at Ouray.

SAN JUAN.

BY G. E. KEDZIE.

There is a well marked unconformability between the Carboniferous and a uniform series of beds apparently Jurassic in the vicinity of the gold belt which is situated high up on the cliff a little below the town of Ouray. This Jurassic series consists of limestones and light colored sandstones with occasional bands of quartzite at the base and variegated green, purple and red sandy shales in thin bands above. These beds average about 600 feet and resting conformably upon the variegated beds is a massive light yellow sandstone occasionally conglomeratic at the base. Then follows a series of sandstones becoming quartzites above, intercalated beds of black argillaceous shale with a band of coal, occasionally near the center of the series and finally compact massive vitreous quartzite, averaging 40 feet, forms the summit of the series, averaging about 125 feet. Further down the valley this formation appears to be much thicker. Above this uppermost quartzite band, which is the ore-bearing horizon, comes the black shale of the Colorado group of the Cretaceous.

The sedimentary beds are cut by numerous vertical dykes, from a few inches to several feet in thickness, having an easterly and a westerly course. These dykes have been the source of an intercalating bed of porphyrite spreading laterally above the upper or ore-bearing quartzite, or in the shales immediately above. In the vicinity of the gold belt this porphyrite reaches a maximum thickness of about 400 feet, further east, however, it becomes mountain masses.

This porphyrite appears older than the ordinary Tertiary eruptions of this region. The limestone bands on the lower portion of the Jurassic, where cut by vertical fissure veins, are in some instances extensively mineralized on either side of the veins.

Again, there are extensive horizontal ore deposits in these limestones, where there are no developments at present to show that they have no connection with fissure veins. These limestone ore bodies are iron and copper pyrites carrying from one to two ounces gold and about the same quantity of silver per ton. In the gold-bearing quartzite belt the ore is principally in the form of oxides of very irregular shape, marking the locality of fractures or fault planes. These ore bodies do not extend into the shales but are exclusively confined to the upper portion of the quartzite.

The reason that the ore bodies occur in the upper portion of the quartzite may be due to the existence of a shear fault along the plane between the quartzites and the shales above it, thereby assisting in opening channels on the fractured quartzite for ore-bearing, hot solutions, but effectually closing any fractures in the compressible shales. The most extensive lateral displacement of a vertical fissure that I re-call at present is thirty-five feet above the Neodisa vein just north of the gold belt. This distance does not however represent the tctal lateral movement or shear faulting, as there are minor faults at other planes.

Hinsdale County, San Juan.

CREEDE MINING CAMP.

This is a recently discovered camp in the eastern portion of the San Juan region, in the neighborhood of the Cañon of the Rio Grande, and not far from Antelope Springs and Del Norte. From Mr. Albert Williams Jr.'s article in the Engineering Magazine of June, '92, we gather as follows:

"The history of this camp dates from the discovery of the Holy Moses mine, June 26, 1890.

"Mr. N. L. Creede, a prospector, found in 1889, some indications to the north of the present camp. Next season he crossed the Divide between Gunnison and the Rio Grande, and located the Holy Moses mining claim and the Cliff claim. Later, some prospectors who had lost three donkeys on Campbell Mountain, the site of the Holy Moses, followed them across the deep gorge and up the steep side of Bachelor Mountain and made the Last Chance strike while resting the climb. Creede immediately took up the extension of the Last Chance as the Amethyst. In 1890 capital took hold and developement began in good earnest, backed by Mr. D. H. Moffat, the well-known Denver banker. In 1891 more prospectors flocked in, and storekeepers, and a little village was established. Still the camp did not attract much outside notice.

Later, when regular shipments of high grade ore began to come in to the smelting works, Creede was talked about and newspapers boomed it.

During last winter many thousands of men being out of employment in Denver, made a stampede for Creede. The ground was then deeply covered with snow and "snow stakes" on real or imaginary claims overlapped each other sometimes three deep. Meanwhile work underground in the mines was steadily pushed, showing large and valuable ore bodies.

The height of the mining fever was in February. There was then a floating population of between 5,000 and 10,000 people who came in by the narrow guage railway. Many came seeking work of which there was but little. Much hardship, as usual in a mining rush, was encountered, and many considered themselves lucky to get away.

Creede proper and Amethyst, at first called Jimtown or Upper and Lower Creede, are in a very narrow gulch, with, at places, walls of almost vertical rock, with a creek flowing through it. There was therefore very little room for the habitation of so many and sites were in demand. An indiscriminate scramble for lots arose, and a wild period of speculation, as much as $15,000 being offered for a particular eligible site. Ingenuity was sorely taxed to find room to plant cabins and tents. Since then, the appearance has changed to well-built houses, hotels and stores. The real estate boom has collapsed and affairs have settled down to a quieter time. The town soon had a water supply, electric lights, banks, two dailies and a weekly newspaper.

Creede is in Hinsdale county in the San Juan region of Colorado, a good region for ore deposits, in which future prospecting may develop other prospects not unlike Creede. For Creede had been frequently run over before by prospectors. The topography is extremely rugged, the cliffs very abrupt. Snowy peaks rise 10,000 to 14,000 feet above sea level. Such regions are the natural '*habitat*' of mineral veins, and the immense exposures of rocky masses afford natural vertical sections of many thousands of feet, and the very ruggedness that makes climbing so arduous, facilitates the search of the prospector, by preventing large accumulations of detritus on the slopes which cover up veins. So veins are more likely to crop out boldly than to be covered by "wash" as are the blind veins of gentler mountain regions.

GEOLOGY.

It is a country characterized by heavy flows of acid eruptive lavas, such as rhyolite, quartz-porphyry and andesite. There appears to be three or more varieties of eruptive rock, indicating successive flows, which are supposed to rest on limestone, and that on granite. The limestone shows up locally a few miles from the camp. It may be part of the great Carboniferous sheet of limestone found in the Leadville and Aspen districts, (and on the flanks of the Sangre de Cristo range, and outcropping from under the outer edges of the great lava sheets of the San Juan near Ouray, at the north, and near Silverton and the quartzite range on the south).

Mr. R. MacMechen, writing on the geology of Creede says: "The chief peculiarity of the section is the enormous preponderance of eruptive rocks without any exemplification of a sedimentary formation. Yet the existence of the latter is easily traced. Just at the lower limit of Jimtown we discover the presence of the Carboniferous, and along the Rio Grande and upon either side of that stream below Jimtown, there can be followed an island of sedimentary formation, some eight miles in length by two and a half in breadth, encompassed by an ocean of highly eruptive material of a much later period." (These exposures of limestone are doubtless the result of great erosion of the super-incumbent lavas.)

"The first good idea of the geological nature of this section is obtained shortly after leaving Wagon Wheel Gap, on ascending the Rio Grande toward Jimtown. Along the stream a horizontal stratum of limestone is observed to the east. This is the Lower Carboniferous, or in mining parlance, 'the blue limestone.' At frequent intervals the stratification is exposed by erosion, and at these points is noted as overlying volcanic rock showing the igneous overflow. North of the Rio Grande, following Willow creek for about one and one-half miles, the northern limit of the Carboniferous is discovered in a highly mineralized state, broken and seamed with dykes of eruptive rock. The eruptive flow again appears south of the Carboniferous island, thus practically enclosing the sedimentary formation."

MINES AND PROSPECTS.

"So far," says Mr. Williams, "two widely separate, nearly parallel fissure veins, with a north-west strike, and a dip of 35 degrees west have produced the most of the ore. These are the Holy Moses and the Last Chance-Amethyst, and extensions along the course of each vein beyond the end lines of the producing mines have received much attention. The bulk of the ore shipped and exposed is a 'dry' siliceous silver ore, with mere traces of gold, carrying iron and manganese and but very little lead. The ore of the Ethel is a heavy lead ore. Some very high-grade ore has been encountered, but the ore shipments have been the regular 'run of the mine' without sorting. Carload lots range between 80 and 150 ounces silver to the ton. Almost no stoping has been done; all the ore has been taken out in sinking and running levels, while opening the mines. So, singularly enough, producing mines show no waste dumps. At first all ore was packed by burrows down steep grades to the railroad. A wire cable was then put in at the Holy Moses, and soon another followed to bring ore down from Bachelor Mountain. Daily ore shipments from Creede in January were 10 carloads, and at the end of April they were 30 carloads. With further development, much larger output is expected."

The Engineering and Mining Journal of March 5, 1892, says: "The Last Chance-Amethyst, the richest mine in the camp, is on a fissure in eruptive rock, opened by four shafts. The deepest is 110 feet, also by drifts along the vein at a depth of 60 feet for every 700. The ore body averaging 4½ feet in width, lying between well defined walls. The ore body consists of white and amethystine quartz, barite, oxides of iron and manganese carrying native and horn silver. The percentage of quartz is so high that the ore is siliceous in character. A remarkable feature of the ore is its solidity, but a few tons of waste having been taken out in the course of the development. There are other veins parallel to the Last Chance-Amethyst, but none have been opened so extensively. The Holy Moses on Campbell mountain, which is one of the most important producers of the camp at present, is on a vein between walls of eruptive rock, which are well defined in some places, but in others much broken. The ore contains more manganese and less quartz than the Last Chance-Amethyst, and occasionally pockets of galena are found."

The Ridge and Ethel mines on Campbell Mountain show a well defined vein and ore consisting of galena and quartz-blende, with low silver contents. The shipments are 50 per cent. lead, 5 ounces silver. The Last Chance "A" carries no lead and 50 to 100 ounces silver. This diversity in character of ore in the same camp, and in veins apparently of the same nature, may seem remarkable though not unusual. Thus the Small-Hopes Bonanza at Leadville, consisted entirely of siliceous silver chloride ore, while the next chute to the east, the Morning Star and Maid of Erin chute, was composed of rich lead carbonate ore, low grade in silver, except near the outcrop. Similarly the Silver Cord ore chute on Iron Hill was distinguished for its gold contents, while the parallel ore chutes on either side did not carry any gold, or but a trifling amount of it. Chutes in the same fissure vein frequently show such differences in character and frequently maintain their peculiarity with great persistence."

"The camp is a good one. Its output this year may place it in the third rank of Colorado mining districts. It is not a 'poor man's camp,' the plums are as yet too few. The mines on the two known ore chutes are yielding well and have large reserves blocked out, which from the regularity of the formation, allow the owners to measure with fair accuracy the value of the ore in sight.

CUSTER COUNTY.

"Comprises the Wet Mountain valley lying between the Wet Mountains or Greenhorn range on the east and the north end of the Sangre de Christo range on the west.

The Greenhorn range is a continuation of the front or Colorado range of Archæan granite with Mesozoic formations resting against its eastern base.

The lofty Sangre de Christo range is a continuation of the Mosquito or Park range and its geological structure but little known, is probably similar, viz., Paleozoic quartzites and limestones, resting upon granite and traversed by dykes of porphyries and other eruptive rocks.

The principal mines are near Silver Cliff and Rosita, an area of ten miles by six. The underlying Archæan is broken through and covered by eruptive rocks consisting of diabase, a heavy, dark rock, andesite and rhyolite, which outcrop at Silver Cliff and Rosita. Silver Cliff city is on the open plain near a 'mesa' ridge on whose cliff face the silver deposits are developed in the 'Racine Boy' mine. The rock of this cliff is a light pinkish rhyolite, showing the laminated fluidal structure peculiar to this variety of lava. A black, glassy variety of rhyolite also occurs.

Outcrops of granite are found on the plains between Silver Cliff and Rosita, implying that the rhyolite rests on underlying Archæan. Two miles north in the Blue Mountains, is the 'Bull Domingo' mine.

The ore deposits are peculiar. The 'Bassick' and 'Bull Domingo,' situated near the northern limits of the eruptive rocks, are among the most remarkable mines.

The peculiar feature of both these mines is that the ore is found in large bodies without any definite boundary forming a coating on irregularly rounded fragments of the adjacent country rock. The popular theory is that the mines are old craters or solfataric openings in which the fragments of rock have been tossed about, rounded by attrition and coated by metallic vapors and solutions.

The country rock of the 'Bull Domingo' is a hornblendic gneiss of Archæan age.

The ore, principally argentiferous galena, forms a regular semi-crystalling coating from one-eight to one-fourth inch thick around boulders and pebbles of rock, and fills the interstices between them. These pebbles are not in direct contact one with the other, but are separated by the metallic coating belonging to each individual pebble.

The galena is covered by a second botryoidal coating of a siliceous nature. The deposit is from forty to sixty feet wide and strikes in a north-westerly direction. The country rock of the 'Bassick' appears to be a 'Breccia' of volcanic pebbles and the ore to be a replacement of the 'Matrix.'

The Bassick deposit is an irregular oval opening from twenty to 100 feet in width, occurring vertically to the present depth of development of 800 feet, an oval well, as it were, in the rocks.

The fragments of rock filling this opening, vary in size from two feet to the smallest dimensions. They are rarely in contact with one another while the metallic coatings surrounding them touch one another. The size of the fragments as well as the quantity of ore present decreases from the center outward without any definite limit having been determined.

In the metallic coating there is a series of concentric layers, the innermost and thinnest consists of sulphide of lead, antimony and zinc, assaying sixty ounces silver and one to three ounces gold to ton.

A second coating lighter in color contains more lead, silver and gold.

The third shell is zinc-blende, carrying sixty to 100 ounces silver, fifteen to fifty ounces gold, with a good deal of iron and some copper.

The fourth shell is of copper pyrites, carrying fifty to 100 ounces gold and silver. These layers are not always constant or complete, they have a crystalline structure; the remaining intersections between the pebbles are filled with Kaolin.

Small fragments of charcoal are found in cavities between the boulders toward the outer edges of the ore body and near the water level. These are sometimes partially mineralized and at others are perfectly unaltered and retain the woody structure.

The greatest depth at which they have been found is 765 feet from the surface.

Silicate of zinc, gray copper, free gold and tellurides of silver and gold are also found in small quantities in the mine.

The "Racine Boy," near Silver Cliff, is an irregular impregnation of the country rock. Chloride of silver occurs in it, the ore is low grade, but occurs in great quantities.

From the Gem Mine a rich nickel ore has been obtained.

From Mr. Whitman Cross of the U. S. Geological Survey we gain some more detailed accounts of the geology of this region.

On the east slope of the Wet Mountain valley, which is a long depression rising north and south between the Wet Mountains and the Sangre de Cristo ranges, this mining center is situated. Silver Cliff is on a gentle valley slope above the broad level. The Cliff is about 50 feet high and is the southern end of a flow of Rhyolite. Three miles east of Silver Cliff and 500 feet above it is a compact group of rounded hills called the Rosita Hills, composed of products from a series of eruptives overlapping one another upon a knob of granite. The main points of geologic interest in these are:

1st. A sequence of eruptions building up the Rosita Hills.

2d. The single eruption of Silver Cliff.

3rd. Periods of decomposition in which the mineral deposition occurred.

Before the main eruptions occurred there were extrusions of syenite and diabase occurring in narrow dikes in Archæan schists. They were eroded in common with the schists for a surface upon which later volcanics outpoured and are of pre-Tertiary origin.

The Rosita Hills eruptions came from single volcanic centers which gave vent to six eruptions. The first three were of andesite lava, next rhyolite, then andesite again, and lastly trachyte. Some of these outbursts were of a quiet nature, others explosive and one was followed by solfataric action which is the ordinary history of a volcano. The first eruptions were explosive and consisted of hornblende with breccia and tufa mud flows. This must have built up a cinder cone partly eroded before the second eruption which was of massive rock. The rocks are of a purplish color, to be seen at the town of Rosita on Purple Hill. Mt. Robinson, The Humboldt and Pocahontas veins are in this. No exact location of these vents is known.

The second eruption covered an area north-west of Rosita, and consisted of a holocrystalline, fine-grained massive rhyolite, with hornblende, augite, biotite in it, forming the northern half of the Rosita Hills. The effusion was quiet and through fissures. Being harder than the surrounding rocks it forms peaks. This biotite andesite is cut by a diorite of plagioclase, orthoclase, augite, magnetite and biotite. This diorite again is traversed by pegmatite veins.

The third eruption was of andesite, forming rounded hills south of Rosita, and differs slightly in composition from the Bunker andesite, and was also quiet.

The fourth eruption was of a violent nature, occurring twice through numerous vents. The massive andesites had plugged the channels, hence relief took place on all sides, and even several miles away to the westward, near Silver Cliff. The rock is rhyolite from a large number of eruptions of small extent. The first very violent, covering the country with ash and scoria, the others more massive, and there were alternations of massive and explosive eruptions. In Wakefield Hill, one mile south of Rosita is a true vent. There is a mass of rhyolitic agglomerate of white pumice Kaolinized with pieces of massive rhyolite and rounded boulders of granite and gneiss. Small pieces of charcoal are also found. This agglomerate is cut by massive rhyolite dykes. Their channels are found on Mount Robinson, Democrat Hill, Knickerbocker Hill, etc. From these vents the lava spread out over low ridges surrounding the hills, and are found in remnants much further from the source than any other rock of the series.

The rhyolite eruptions at Silver Cliff are on a much larger scale than at Rosita. The Racine Boy Mine is in the Geyser shaft, has penetrated 1,100 feet of horizontal breccia stuff, and is still in it. This shows that a lake existed here, gathering materials from a vent near by. Round Mountain represents the source of Silver Cliff lava flow.

Beneath the banded rhyolite of the cliff is a zone of round boulders, with cavities containing ore. The "eggs," as they are called, were embedded in a very soft Kaolin clay. In other places glassy pilchstone was the matrix.

The same glass also occurring below the boulder zone. These boulders are huge spherulites, pumacy radiate crystallizations in the lava flow, to which both rhyolite above and pilchstone below belong. The clay is the result of a decomposition of the pilchstone, consisting of Kaolin and opaline silica.

Succeeding the rhyolite came another andesitic eruption through long fissures penetrating all the older rocks. The rhyolite is cut by these andesite dykes, and surface flows of it rest on the rhyolite. It is a mica-augite-andesite. Dykes of it occur in Rattle Snake Hill. Last there came true trachyte by the largest and longest of fissures, and penetrated all previous groups. It was not explosive in character. Game Ridge, near Rosita, represents its outflow, and the dykes extend from Rosita to the west base of the hills.

The mountains built up by the lavas were never much larger than now, because dykes and flows appear. The changing of the rocks such as rhyolite by solfatanic action is quite what is found in modern regions. This took place immediately after the rhyolitic eruption, that is, the closing phase of the rhyolitic period of eruption of a volcano. It is a hard, rough, porous rock like coarse dolomite, composed of quartz and "alunite," which is a hydrous sulphate of alumina and alkali, closely allied to alum but different in physical characters. It is hard as feldspar, insoluble except in sulphuric acid, occurs in Hungary, Italy and the Island of Milo, as products of sulphurous vapors upon rocks rich in alumina and alkalies. The alunite rock of Tolfa near Rome, was for centuries quarried for alum, extracted after slow roasting by leaching with water.

The rough rock of Democrat Hill is two-thirds quartz and one-third alunite, the original rock structure having been destroyed. In Mount Robinson, near Rosita, the crest is due to a dike similarly altered to alunite. The alunite has here been further decomposed and extracted, portions of its alumina remaining in crystals of hydrous alumina called "diaspore."

The Bassick mine occurs in the throat of a volcanic vent on the eastern edge of the eruptive area. It was an independent eruption of andesite. The shaft is down over 1,400 feet in volcanic agglomerate, whose surface distribution is very limited. This agglomerate consists of boulders of several kinds of andesites mingled with Archæan boulders. The boulders are rounded by attrition, bedded in gravel and sand derived from the same action. Occasional fragments of charcoal are found at a depth of 800 feet from the surface. The agglomerate fills a typical 'neck' of a volcano or channel below the crater.

The ore of the Bassick appears as concentric zones about the boulders and as a replacement of a gravelly matrix. The entire mass has been permeated by thermal waters, which have decomposed the rock fragments and deposited quartz, opaline, silica and kaolin in abundance.

Since the eruptive period, decomposition and erosion have followed. Decomposition was extensive, by it large areas of andesite are bleached by hot waters charged with various solvents, and the ore deposits are connected with the same. It is probable that this volcanic area was an outlier connected with still greater eruptions to the south-west of it.

Note.—From Prof. B. F. Sadtler, of the School of Mines, who has just returned from Creede, (February 26, 1893,) we learn that in the district south-west of the main fissure vein area, *i. e.*, of Bachelor Hill, there is outcropping along the Rio Grande River and lower part of its tributaries to the north, for several miles, the Lower Carboniferous rocks, extending to, and underlying to a greater or less extent, the eruptive rocks before mentioned. Prospecting developments show these strata to contain numerous intrusive sheets and dykes of eruptive rock. Besides the blue siliceous limestone seams of highly carbonaceous black shale of the upper series have been found in several of the mines. The 'contacts' in this carboniferous series have been found more or less mineralized, and the Monon, Yellow Jacket and some other mines have already shipped ore of a good grade, whilst the actual presence of ore as well as good indications in other prospects make it probable that the 'lime belt' in Sunnyside and adjacent districts, together with a similar formation at Spar City, may become important producers at an early date. The limestones dip about 15°, and to the south-east. The valleys of erosion afford numerous tunnel sites on the cropping of the contacts, making a district in which mining will probably be very cheap. It is also closer to the Rio Grande Valley than Creede. It is not improbable that Creede itself is at an unknown depth underlaid by these ore-bearing limestones.

FREMONT COUNTY.

CRIPPLE CREEK MINING CAMP.

*The lately discovered Cripple Creek gold mining district lies at the western base of Pike's Peak and has an area of about 20 miles square. The district is amongst the mountains with an average elevation of 9,000 feet. The surrounding scenery is very pretty, the camp lies in a park basin, one of a series of parks between Pike's Peak

*From Great Divide.

and Mt. Pisgah, 10 miles south-west of Pike. It is 70 miles from Denver, 20 miles from Colorado Springs and 44 miles from Pueblo.

The mineral belt is about 8 by 12 miles, giving a territory of about 100 square miles. The mountains or hills of the basin are smooth and softly outlined, wooded, with pleasant valleys and gulches.

Repeated trials have been made to find gold in this district. In the sixties, Hayden's party passed through but missed the ore deposits. In 1874 a tunnel was dug and abandoned on Arequa creek. Good mines are now opened on each side of this creek. In 1879, others dug a tunnel in Poverty gulch, but abandoned it, just missing the ore. This is near one of the present producing mines.

Finally, in 1891, several claims were located. It began to be noised about that there was something in Cripple Creek, prospectors moved in. Colorado Springs men were first in the field. At the beginning of March 4,000 men, and by June 8,000 men, were in tents and temporary shelters on the ground.

The Blue-Bell was the first mine opened. Assays from the surface averaged $80 per ton. The ore was three parts silver to one gold. The shipping mines were the Anaconda, Hub, Buena Vista, Marguerite, Ironclad, Princess, Jack Pot, Jeff Davis, Orphan Bell and others. The Anaconda at present is the leading mine, producing mainly gold.

GEOLOGY ACCORDING TO R. C. HILLS.

"The principal ore bodies at present developed, occur in consolidated volcanic ash, resting on upturned granite and gneiss of the western foothills of the Colorado range. In places, dykes and intrusive bodies of andesite, traverse the tufaceous rocks of the district, and in the case of the Gold Key, this is the material which having been more or less altered and mineralized, contains the pay-ore. The majority of the ore bodies of the district may be properly described as mineralized. Zones, where the decomposition, Kaolinization and accompanying deposition of gold, has taken place along zones of multiple faulting and fracture. There is good reason to believe that the zones themselves will continue downward, through the volcanic tuff to the granite basement. It is equally probable that the pay ore, subject to the breaks in continuity incidental to deposits of this character will persist to the same depth, and though a direct connection has yet to be shown between the zones in the tuff and the veins found in the basement rock, the occurrence of gold and granular fluorite as minerals common to both systems of deposit, argues that such a connection will be demonstrated eventually. For the same reason the presumption is strong that the mineralizing process was not one of lateral secretion, such as we see in the San Juan Mountains and elsewhere, but that the source of the precious metals was at least as deep-seated as the granites of the districts."

Another writer thinks "there are two classes of eruptive rock, one, andesite, the other, rhyolite. The veins exist in the 'porphyry' and sometimes between the 'porphyry' and granite. The vein matter is mainly quartz and mineralized 'porphyry,' with fluorspar, tate, etc., in small quantities. The eruptive rock overlies the granite, but at times seems to have intruded itself into crevices underlying portions of the granite. Large masses of granite are sometimes included in the eruptive rock. The placer grounds adjacent appear to have values then if water can be brought to bear on them."

HUERFANO COUNTY.

Ore occurs in the Spanish Peaks. The ore is galena, pyrite and gray copper, occurring in a gangue of quartz in the joints of the porphyry. In the "Monarch" mine the veins are in the porphyry which composes these majestic eruptive mountains whose history is that of a vast number of dykes emanating from a grand center of eruption which constitutes the core of these peaks.

GENERAL REMARKS ON COLORADO ORE DEPOSITS.

These examples we have selected from the principal mining districts of Colorado to illustrate the principles in the preceding part of this work, afford us good types of the geological formations in which the ores are principally found, as well as their typical mode of occurrence, viz: The Archæan granite series with its fissure veins, the typical volcanic region of San Juan, in which fissure veins also occur in enormous masses of eruptive rock only, and the sedimentary series, such as limestones and quartzites, penetrated by intrusive eruptive rocks in which the ore occurs in bedded deposits or pockets.

There has been and may still exist a prevailing prejudice in tavor of fissure veins on account of their supposed steady reliability to great depths, and against bedded deposits or "blanket veins," as they are sometimes called, especially when they occur in limestone, on account of their supposed uncertain continuity for any great distance.

The developments of Leadville and Aspen have shown this prejudice to be unfounded, at least in Colorado, and have almost overturned the scale in favor of bedded deposits in limestone, since the riches derived through a few years from these formations have far exceeded all that has been obtained from the fissure veins of Colorado in granite rocks in the whole course of Colorado history. It is true that sometimes ore deposits occur in a series of almost isolated and disconnected "chambers" or "pockets" and that much labor and expense is spent in hunting for a second pocket after the first has been exhausted, but they are the exceptions in Colorado rather than the rule, and quite the same thing not unfrequently occurs in the more popular fissure veins. A "pinch" or a practically barren interval of an unknown length may occur between one productive part of a fissure vein and another.

In the Leadville ore deposits the ore not only occurs as a broad sheet or blanket between the overlying porphyry and the limestone, but also descends at intervals in large and irregular pockets into the mass of the limestone itself. The same occurs at Aspen also. There has been far less difficulty in both these camps of following down these blanket deposits with occasional pinches and widenings, and pockets in comparatively soft limestone gangue than in pursuing the steep downward course of a fissure vein in granite or eruptive rock with its hard gangue of quartz.

As to the continuity and reliable lasting powers of these so-called bedded blanket deposits, so far as we can judge from those at Leadville, which have been worked now for upwards of ten years, there seems nothing against their lasting for centuries, or to the limit of depth to which mining operations can be carried.

The ores in limestone, from their oxidized character, are easier treated at the smelter as a rule than those found in fissure veins.

As for degree of richness, we have but to look at the late extraordinary rich developments at Aspen to show that bedded deposits in limestone can equal and far surpass in richness and quantity the average fissure veins in granite rocks, so that the answer of an experienced mining man to the question whether he would rather have a fissure vein in granite or a bedded deposit in limestone, had some reason in it when he replied, "Give me a limestone deposit, every time." We do not underrate fissure veins, but we think they have been overrated to the disparagement of other forms of mineral occurrence quite their equals, and often their superiors.

With regard to fissure veins, from what we have said it will appear that in Colorado, at least, we have very few that will answer to the orthodox type, as represented in some of our text books, viz., a once wide open fissure with well defined walls that has been gradually filled by mineral solutions ascending from heated depths below.

We do not think the original fissures were wide, or at least so wide as some of the fissure veins now are, such as fifty to one hundred feet in width, but that they were rather narrow cracks, such as produced by faulting and jointing, or lines of weakness between stratification planes which were worked upon by solutions oozing from the adjacent country rock, robbing that rock of the metal elements minutely contained in its constituent minerals, and redepositing them in various combinations in a more available and crystalline form in the fissure or line of weakness. The great width of some of our veins we attribute rather to the altering, corroding power of these solutions on the country rock than to the original width of the fissure.

The fissures or fault lines of some of the profound faults in our mountains do not present a wide open fissure abyss, but narrow cracks sometimes almost welded together again by heat and pressure; the adjacent rock in the immediate proximity of the fault is also much broken, cracked and fractured. Upon just such a line of weakness and of broken rock, mineral solutions working, would dissolve, alter and replace portions of the broken rock constituting a wide vein, whilst other portions would be left unsubstituted and constitute a breccia, or the solutions working around large fragments would present us with the phenomena of those horses and split veins we see so well represented in the fissure veins of San Juan and elsewhere.

The medium for filling these fissures with veinstone and metal was in all cases water, probably heated and charged with various alkalies and salts.

The favorite circumstances for rich ore occurrence in Colorado are in what are called "contacts." The ore body, lying between two rocks of a different character, usually between an eruptive porphyry and some other sedimentary metamorphic or non-eruptive rock. These "contacts" may occur both in connection with fissure veins and bedded deposits in both the granitic and limestone districts.

It is important then for prospectors to keep a lookout, not so much for one particular kind of rock, but the juncture of two different rocks, one eruptive and the other not, and prospect at the line of juncture.

The eruptive rock is not always necessary in immediate contact with the ore or ore-bearing rock, but may be sufficiently near to influence rocks in its vicinity with mineral solutions emanating from it. Not a *single* circumstance but a *combination* of circumstances which we have detailed in this work constitute an ore-bearing area.

Sometimes a miner may mistake the plane of a fault for a true contact; he may have been perhaps for some-time following a dipping or blanket vein and encounter suddenly an abrupt wall of granite or possibly porphyry, the result of a fault, which, so far from being a desired contact, is practically the terminus of his mining operations. Cases have occurred where the miner has still pursued the even tenor of his way and gone on tunneling in the granite with, of course, no results.

We cannot too strongly emphasize what we have said in the body of this treatise relative to the popular, mischievous fallacy of supposing that richness must necessarily increase with depth, and that though evidences seem poor for moderate depth below the surface, yet "if we only go deep enough we are pretty sure to strike it rich."

There is no scientific reason one way or the other for this, and experience is rather against richness with great depth. Nearly all our gold veins are richer and more valuable near the surface, and in the oxidized portion than with depth. Oxidized ores of all classes within moderate depth from the surface are, as a rule, richer and easier treated than those found at great depth. Consideration of this fact would prevent much money being risked or wasted in expensive, needless cross-cut tunnels in dead rock, at some low point, in hopes of tapping the vein at great depth. It should also prevent parties unacquainted with mining in expecting too much with depth from lodes that have not proved very profitable near the surface. Notable and important exceptions we admit often occur to this general rule.

In examining a mining property with a view of forming estimates of its value, a thorough system of assaying should be pursued in various parts of the ore body, especially in the more average and poorer parts of the vein. Rich specimens should be studiously avoided.

Assays from such would give a most fraudulent report of the mine. There is a certain district in Arkansas from which glowing reports have been made, backed up by these specimen assays, whilst the region is utterly valueless. To show a specimen from a mine coated with native gold or silver is a common device of the unscrupulous man who has a "hole in the ground" to sell to some "tenderfoot" who is struck with mining fever and is too ready to believe what "he sees with his own eyes." By and by "the proof of the pie will come in the eating thereof."

DESCRIPTION OF FRONTISPIECE.

The frontispiece represents both sides of the Roaring Fork Valley in which Aspen city is situated, and also looks up toward the Grand Cañon of Roaring Fork, where the river issues through its walls of granite in the Sawatch range. On the right hand side of the picture we see Aspen Mountain on which are so many of the principal mines. These are located principally on the slope of Spar Gulch and in the bed of the adjacent Vallejo Gulch. In the Spar Gulch are the Durant and other "Apex" mines, and in Vallejo are the principal "Sideline" mines, both working in the same uplifted belt of carboniferous limestone, and both, happily, of late consolidated by a compromise. The centre of Vallejo Gulch is occupied by a great thickness of eruptive diorite lying more or less upon top of the basined and faulted limestone, and separated from it by a belt of black shale. On the opposite side of this, on the right, the limestone again appears by a process of folding and faulting, and is pierced by several tunnels, amongst them the Late Acquisition and Pioneer Mines. The limestone and some quartzite rest upon granite which forms the central nucleus or basis of the mountain which, as the engraving shows, is hollowed out into a thin shell like the half-section of the crater of a volcano. On the north-western slope of this shell are seen the same silurian quartzites and overlying carboniferous limestones leaning against and folding around the granite with a somewhat different direction of strike and dip from the beds on the opposite side of the shell in Spar Gulch. Ore deposits are found on this side also, but not so abundantly as on the other; the Pride of Aspen, Mary B and Homestake tunnels have found ore. Beneath this slope is Castle Creek, flowing into the Roaring Fork. This side of the Roaring Fork, together with the city of Aspen as it appeared two years ago when the writer sketched it, together with the principal mines on Aspen Mountain, are best shown in the Frontispiece, with the accompanying section. On the left hand of the frontispiece, the small but important hill called Smuggler Mountain is seen. Its importance consists in the rich developments of ore that have been found in the Smuggler, J. C. Johnson and Regent mines, all of them, as on the opposite mountain, apparently on the same line of contact. The geology of this mountain is somewhat obscured by enormous coverings of glacial drift, but from the developments in the mines it appears to correspond to the same formations as are more clearly developed on the opposite Aspen Mountain in Spar Gulch. The mountain is of less size than that of Aspen Mountain, apparently from the strata not being there reduplicated by faulting, as on Aspen Mountain, but formed from a single series of strata consisting of Silurian quartzites resting on granite, with dolomitic limestone (short limestone) and black shales above them, and also some diorite porphyry (if we may judge from materials found in the dumps) included, as on the other side, in the black shales. Though the ore bodies are well developed in the mines and of much the same character as on Aspen Mountain, the presence of the blue limestone of Spar Gulch is not so apparent; its seeming absence might be accounted for by its having been more completely dolomitized on this side than on the other, or by its having been partially or completely eroded away or even replaced by ore, rather than to suppose the strata is different or the ore belt at a different level on this side than on the other. It is probable that a fault corresponding with the bed of Roaring Fork will be found to separate this mountain from Aspen Mountain. The dip of the strata, as shown in the J. C. Johnson mine, is much steeper than that on Aspen Mountain, and increases in steepness with depth. The strata on the opposite side of Hunter's Creek are red sandstones, and probably belonging to the Jura-Trias, or extreme upper Carboniferous. In the foreground is a pretty little artificial lake, a favorite resort of the Aspenites. Behind the lake appear some of the houses on the skirts of the city.

SAN JUAN FISSURE VEINS. (PLATE NO. 9.)

The illustrations, Figs. 1 and 2, representing "horses" in great fissure veins, were from sketches by the writer, of some fissure veins in the Animas Cañon, between Silverton and Animas Forks. The veins are of good width, from fifty to one hundred feet in places, and are clearly defined on the side of the cliffs of the cañon, whose height is between 2,000 and 3,000 feet. Fig. 3 is from Dr. Hayden's report, of two series of fissure veins cutting one another diagonally, opposite Howardsville, in the same cañon. Two mammoth master veins are cut by a series of minor fissure veins having a different direction or strike.

SHEEP MOUNTAIN FOLD AND LONDON FAULT. (PLATE NO. 3.)

The picture of the "Sheep Mountain fold and London fault" is a striking example of structural geology, showing how a mountain range, such as the Mosquito Range, is formed by a series of folds, passing at their greatest tension into profound fractures or faults, resulting from tangential pressure or compression, whose ultimate cause is the gradual contraction of the earth's crust around its diminishing, cooling nucleus.

It is not often that nature supplies us with so remarkably clear a section of her hidden structure as that presented in the Sheep Mountain fold in Horseshoe Gulch. In it the hard Silurian quartzite, together with the overlying Carboniferous sandstones, shales and limestones, and a cap of white porphyry, are seen bending over in a steep but complete arch almost as perfect to the eye as one formed of artificial masonry.

The exact line of the London fault, which is indicated by the little valley or sag between it and the adjoining Lamb Mountain, is, as is usual in the case of faults, obscured by *debris* and vegetation. If the *debris* were removed we should probably find the fold passing into an S-like form, broken near the base by a nearly vertical crack, with Silurian strata and Archæan granite forming the east wall of the crack abutting against upper Carboniferous grits on the west wall of the fissure. There is consequently a slip here of many hundreds of feet. Some idea of the amount of slip may be obtained by noticing that the Weber grits of the upper Carboniferous, marked g, lie properly on top of Sheep Mountain. The fault has dropped them down to the bottom of the valley, where the upper portion of them is seen outcropping at the base of the adjacent Lamb Mountain. A portion of them, turned up by the fault at a sharp angle, is observable on the east side of Lamb Mountain, reclining against eruptive white porphyry. In the grits and shales were found well defined impressions of true Carboniferous foliage, such as the Equiseta. The top of Lamb Mountain gives us a good example of a laccolite of eruptive white porphyry, from which the overlying and once over-arching sedimentary strata have been removed by erosion. A dyke of white porphyry is found cutting through the underlying strata and connecting with the great laccolitic mass, which rests intrusively on the Weber grits. This is one of the numerous vents from which the great white porphyry sheets came.

SUMMIT OF MOUNT LINCOLN.

Mount Lincoln is a typical example of a mountain formed by a net-work of dykes and branching sheets of hard porphyry intruded between less enduring strata of silurian quartzites and carboniferous limestones, welding together the mass into a compact form which has resisted erosion and left a prominent peak 14,000 feet above sea level and 4,000 feet above the adjacent valleys of erosion. A dyke of coarse-grained quartz-porphyry, containing large perfect crystals of feldspar, has come up through the granite, piercing also the overlying paleozoic strata, sending out intrusive sheets, and near the top intruding an enormous thick reservoir mass between the strata, in the form of a laccolite, from which the overlying and once over-arching strata has been removed, leaving the great columnar mass exposed, which now forms the summit of the peak. This dyke has also been cut by newer dykes and sheets of a dark green porphyry called porphyrite, which has also sent out horizontal sheets between the silurian strata, and these sheets have again been cut by a dyke of white porphyry. The feeding dykes of both forms of porphyry are here traceable down into the granite forming the base of the mountain. The principal ore belt, upon which the Russia, Present Help and other mines are located, is near the summit of the mountain, at the contact of a porphyry sheet with the carboniferous limestone. The Present Help mine is one of the highest in the world.

SECTIONS ILLUSTRATING THE GRADUAL DEVELOPMENT OF THE LEADVILLE AND SOUTH PARK REGION. (PLATE NO. 12)

Figures 1 and 2 are ideal, and meant merely as illustrations of Mr. Emmons' hypothesis, with a view to make the text more clearly understood.

Fig. 1 represents all the strata, from Silurian to Cretaceous, as lying conformably on one another at the bottom of the Cretaceous sea, between two granite islands—the one on the right constituting the "nucleus" of the modern Front Range, the one on the left of the Sawatch Range. Between the two is the area now occupied by the South Park, the Mosquito Range, the Leadville district and the Arkansas Valley. These conformable strata were, according to Emmons, penetrated by dykes and intrusive eruptive sheets whilst lying below the sea, and mineralization took place about the same time.

Fig. 2 shows all these strata, with their included eruptive sheets and ore beds, crumpled up between the Front Range and the Sawatch Range into the Mosquito Range and South Park Basin, which took place at the great mountain uplift at the close of the Cretaceous.

Fig. 3 is an actual average section of the region of South Park and the Leadville district as it now is, showing how the folds passed into faults, and how the tops of the folds and uplifted cliffs of the faults have been planed down by erosion.

The figures also show in somewhat the same way the progressive history of the eastern and western foothills on either side of the granite axes; how they were originally horizontal, how they were folded up and how, by erosion, they have been cut down into low hogbacked ridges.

THE COLORED GENERALIZED SECTION OF THE ROCKY MOUNTAINS IN COLORADO, SHOWING THE POSITION OF ECONOMIC PRODUCTS IN THE DIFFERENT GEOLOGICAL HORIZONS AND STRATA.

This section, which illustrates portions of Part I. and II. of this treatise, represents a general average section of the Rocky Mountains in Colorado, made up from typical sections of the country where the strata are best exposed.

Thus the Archæan may be exemplified by the Sawatch and portions of the Mosquito ranges.

The Paleozoic, consisting ot the Silurian and Carboniferous, by the Leadville, South Park and Aspen districts.

The Triassic and Jurassic, by the rocks of Morrison or by the Garden of the Gods at Manitou.

The Lower Cretaceous, to the Laramie coal beds, also by the section near Morrison, along the banks of Bear Creek.

The Laramie Cretaceous, including the coal beds, by the section at Golden City, along the banks of Clear Creek.

The Tertiary, by the table lands or "mesas" of the Divide near Sedalia.

The Quaternary and Tertiary, by the strata underlying Denver and forming the Denver basin. The Quaternary pebble beds are distributed at intervals over the eroded tops of all the formations from Archæan to Tertiary, and from the high mountain placers in glaciated cañons to where the principal streams *debouche* on the prairies.

The *Archæan* is shown to consist of granite, gneiss, schist, etc., traversed by dykes of eruptive rock and by fissure veins carrying silver, gold, lead and iron, and constitutes the axis of the high mountain region.

The Silurian and Carboniferous, constituting the Paleozoic era, rest on the granite, and are traversed by various eruptive porphyries issuing from the underlying Archæan, in dykes, and spreading out between the Paleozoic strata in intrusive sheets, or in thick laccolitic masses, sometimes by erosion, forming the caps or peaks of prominent mountains. The quartzites are shown to be principally gold-bearing and the limestones silver and lead bearing, particularly at their contact with eruptive porphyries. Iron is found throughout the series. The great thickness of *Weber grits*, consisting of coarse sandstones, shales and quartzites, with a few limestones, are generally unproductive. A few thin seams of semi-anthracite coal occur at Aspen and Leadville, and towards the upper portion some limestones, penetrated by porphyries, produce important deposits of silver and lead in the Ten-Mile district at Kokomo, of which the Robinson mine may be taken as typical.

The Paleozoic rocks are generally confined to the high mountain region.

The *Mesozoic* rocks, consisting of the Trias, Jurassic and Cretaceous, are more characteristic of our foothills and hogbacks, and yield us no precious metals, but many valuable economic products.

The Trias yields good red building stone at the Glencoe quarries, on Ralston Creek; also white siliceous sandstone for glass manufacture, and red flagging stones in Boulder County.

The *Jurassic* yields quicklime from quarries in limestone, at several points along the foothills; also beds of gypsum for plaster of paris, and some fine red building sandstone. The formation is remarkable for the dinosaurs, discovered at Morrison and Cañon City, and for the first discovery of oil on Oil Creek, near Cañon City.

The base of the Cretaceous, called the Dakotah group, consists of a thick bed of white sandstones, quarried at Morrison for building stone, and in the center of the group is a belt of the finest blue fireclay in America, quarried between Golden and Morrison, and extensively used for fire brick, etc. This formation generally forms a prominent hogback along our foothills.

The *Colorado Cretaceous* consists first, of a bed of black shale, with concretions of inferior iron ore; secondly, of white limestone, much quarried along the foothills at Golden, Morrison, Cañon and elsewhere for flux for the smelters; thirdly, a bed, sometimes over 2,000 feet thick, of drab shales and clays, near the middle of which is a sandy layer, which has been tapped by the oil wells of Florence, near Cañon City, and has so far yielded most of our oil production.

The *Laramie Cretaceous* has a thick bed of white sandstones near its base, which is utilized for building sandstone, and quarried at Trinidad, Cañon City and elsewhere. In this sandstone formation lie the principal coal seams, the largest and most worked averaging six to eight feet in thickness. Beds of inferior concretionary iron ore are also found near the coal, and also beds of plastic clay and inferior fire clay.

The *Tertiary* beds of clays and sandstone, underlying Denver, have given us our artesian wells, at depths varying from 300 to 1,000 feet, and on the Divide, between Denver and Colorado Springs, the Tertiary table lands are capped by a pink rhyolite lava, much used as building stone.

The *Quaternary*, consisting of drift, pebbles and clay, can be found on the banks of our streams and underlying our farm lands, or on the sides of the deep cañons on the high mountain areas. It forms our placer beds, which yield more or less gold, and in several localities the fine clay makes good red building brick. Above this rests the black soil of the farm lands, with their crops of grain, grass and vegetables.

This section can be applied, with modifications, in a general way, to various parts of Colorado, and may act as a rough guide or map to the prospector in search of precious metals or other economic products.

INVESTMENTS IN MINING PROPERTIES.

EXTRACTS FROM AN ARTICLE IN "ENGINEERING MAGAZINE," BY A. WILLIAMS, JR.

Driving adits, drilling, blasting, timbering expenses can be safely calculated.

To avoid uncertainty a mine should be well opened ahead of the stopes.

There is no reason for wild milling experiments. Smelters buy ore at 95 per cent. of its assay value, and good mills save 80 to 90 per cent.

Careful sampling, plenty of assays with test mill runs and sample lots shipped to a smelter, will show what can be expected of an ore. These will decide the proper process to be used.

Ore buyers and smelting works will accept any ore of value, no matter how rebellious. By public sampling works ore can be sold in open market to the highest bidder. There is thus little trouble in disposing of a mine's product. The miner receives immediate returns for his output. The metallurgical business is being concentrated in large custom works at favorable central points, where fuel, etc., are cheap, and where they can operate best by commanding a great variety of ores. Much depends upon rate of freight as to profit or loss.

The product of precious metal mines is at once marketable. Gold and silver ore and bullion can always be disposed of. The three points to be considered are, the mine itself, the way it is handled, the financial management..

A good "company mine" should be a large one, worked on a large scale. A number of small mines pay handsome dividends to a single owner, but not to a large corporation.

California corporations operating Nevada mines offer their shareholders rarely less than 25 per cent. dividends, which, on a capitalization of $10,000,000 on 100,000 shares would mean $25,000. One such dividend a year would be creditable for a mine owned by one or two persons. A good "company" mine should be big enough to be worked by a large force of men to insure steadiness of output. A rich narrow vein may be good for individual ownership, where only a few men can work, but for a company mine a large deposit of lower grade capable of extensive opening and large ore breasts with regular output is the best.

The most reliable gold mines have been from very low grade ores, but large regular deposits. In California

$15 a ton is high enough for a company if the ore is plentiful. In the large deposits of the Black Hills and Alaska $5 is profitable. The most famous mines have not been high grade ores. So in silver. On the Comstock the heart of the "big bonanza" was only $80.

The silver mines of Montana are not nearly as high in average grade.

Undeveloped prospects should be avoided by outside investors, and also large groups of insignificant claims. A whole group is no better than a single location, as it dissipates effort over many scattered openings.

Why, it may be asked, does the owner want to sell a mine? Holders want more money than is in sight. Sometimes a good mine may need much preliminary outlay, and the holders have not the cash. Some mines are sold by parties interested in other locations and willing to clean up on part of their holdings. It is not safe to buy a mine on its record alone, for the reason that the more mineral that has been taken out of a mine the poorer the mine is. Owners are often anxious to sell a mine that they know is practically worked out. The life of a mine is sometimes very short owing to the rate at which we can now develop it.

The surroundings of a mine have much to do with its value. Every dividend-paying mine should have a healthy bank account to tide over any accidents or delays in the mine, as a reserve fund.

Geology of Other Western Ore Deposits.

THE PACIFIC SLOPE.

The Pacific and Western ranges are characterized by distinct mineral belts. The Pacific Coast range, by quicksilver, tin, coal, and chromic iron. The next belt is that of the Sierra Nevada and Cascade Mountains of Oregon, which on their western slope carry two distinct zones, a foothill chain of copper mines, and a middle line of gold deposits extending to Alaska. Along the eastern base of the Sierras is a zone of silver, in which lies the Comstock mine. This belt stretches south into Mexico containing a chain of silver mines, mostly in volcanic rocks. Other belts of silver and lead lie east of the Sierras, amongst which the mines of Eureka, Nevada, are the most celebrated. Then through Central Mexico, Arizona, Central Nevada, Middle Idaho, there is a line of silver mines in the older rocks. Through New Mexico and Western Montana, lies another zone of argentiferous galena lodes, and again to the east the New Mexico, Colorado, Wyoming and Montana gold and silver belt, forms a well defined and continuous chain of deposits. This parallelism of mineral belts is due to the great structural and geological features of the country.

NEVADA.

THE COMSTOCK MINE (BECKER).

The most celebrated mine of the West, is the Comstock mine, in the Washoe district of Nevada, on the east slope of the Virginia range, an off-shoot from the Sierra Nevada.

The Washoe district, Nevada, is characterized by great out-pourings of massive volcanic rock, underground, these are much decomposed. Hornblende and augite in these decomposed rocks pass into a green chlorite, feldspars into calcite and Kaolin. There are also enormous masses of clay in the Comstock due to attrition of vein matter.

The rocks of the district are granite, schists, slates, limestones, eruptive diorite, quartz porphyry, an older and a younger diabase, two hornblendic andesites, one older than the other, also augite andesite, and basalt. The quartz porphyry is what Richtofen called "propylite" or "dacite."

The younger diabase or "black dike" is not porphyritic like the other rocks.

There are many evidences of faulting in connection with the vein, such as irregular openings in the vein, "horses," slickensides, rolled pebbles in the clays, and crushed quartz. Also east and west of the vein, there is a division of the rocks into sheets, showing evidence of movement on their smooth faces. This faulting movement was an upward one of the foot-wall. The cañons of the adjacent range were produced by faulting and since this faulting the erosion has been slight.

The succession of rocks is: 1st, granite at base; 2nd, on this schists; 3rd, diorite; 4th, quartz porphyry; 5th, earlier diabase; 6th, later diabase; 7th, earlier hornblendic andesite; 8th, later augitic andesite; 9th, hornblendic andesite; 10th, basalt.

The sedimentary beds were laid down on the granite and are much broken and altered. They are of Mesozoic age. They are much charged with graphite and pyrite, which explains the origin of the hydrogen sulphide in the mine. Then follow the eruptive rocks.

The diabase is important because associated with the ore deposits, and forming the "black dike" which occurs on the west wall of the vein. This "black dike" is the only important dike in the district, and shows, though very thin, that the fissure on which the Comstock lode afterwards formed, was first opened in Pre-Tertiary times before any faulting or dislocation took place, the faulting being a comparatively recent phenomena. The basalt is very limited and has no connection with "solfataric" action.

CHEMISTRY OF THE LODE.

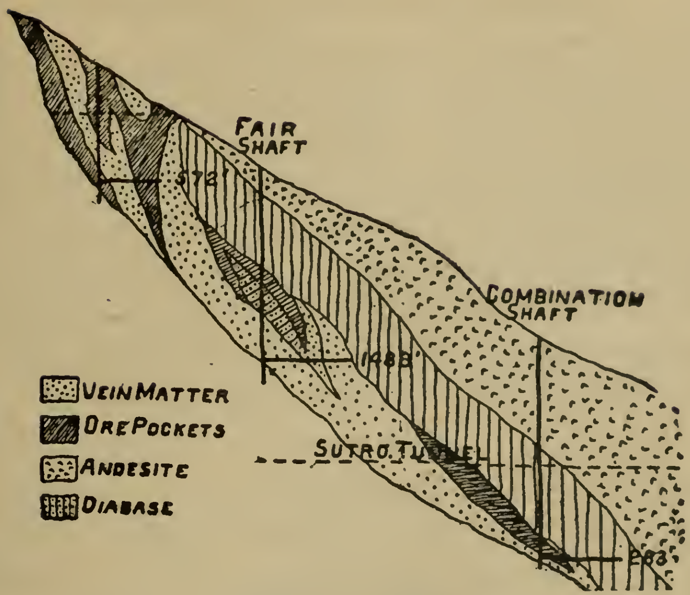
This is shown mainly in the various changes in the decomposition of the rocks, and the products of pyrite, chlorite, etc., from minerals in the rock. The "diabase" microscopically shows the presence of much precious metal, mostly in the augite, more in the fresh than in the decomposed rock. The ore came from this. The gangue is quartz, in which the ores are finely disseminated, consisting of argentite, native silver and gold, with twenty times as much silver as gold. The reagents were waters charged with carbonic acid and hydrogen sulphide, producing from the elements of the rocks, carbonates, sulphides, alkalies of earths and free quartz. Quartz and sulphides are soluble in solutions of carbonates and sulphides, and this might on solution be carried into interstices of the vein and there deposited by relief of pressure and cooling. Evaporation also assisted precipitation no doubt.

HEAT IN THE MINE.

Great heat was met with in the upper levels and increased with depth, the lower levels being intensely hot, averaging 170° F. A partial immersion would kill a man. The air is almost equally hot as the water, and its intensity is only kept down by extraordinary artificial ventilation. Some of the old drifts where there is no ventilation cannot be entered by the miner. The air is very moist. All this is the result of old solfataric action, like that which is at present going on in the Steamboat Springs, but six miles distant. The great body of water in the Comstock, appears to be due to the Comstock tapping, like an artesian boring, underground springs, leading from the crests of the great range. And the conduction of heat comes through moist rock, and the origin of the heat from great depths. The temperature rises three degrees for every 100 feet and the water is at boiling heat in the 4,000 foot level.

THE LODE.

The lode is a long wide belt of vein matter ramifying at each end into divergest branches. The cross section shows a regular foot-wall dipping east 33° to 45°. On the top secondary fissures diverge from the main lode, penetrating the east wall, and forming "horses." Below the horse the vein is narrow. The hanging-wall is of older diabase, much decomposed. The foot-wall is granular diorite. The "black dike" follows the foot-wall in places. The contents of the vein are fragments of "country rock" and quartz. The ore is argentite and free gold, and the



COMSTOCK FISSURE.

distribution of the ore is very variable. The diorite carries a little gold and no silver. The diabase is silver-bearing and also carries some gold.

There are concentrations or bonanzas of ore in masses of quartz associated with diabase. The quartz is crushed like commercial salt by faulting, which appears to have taken place by a succession of small slips. The ore body bonanzas occupy spaces which once enclosed only fragments of rock. The course of the ascending waters was influenced by narrowness of the fissure in the lower levels and forced its way into capillary fissures, seeking gradually the main fissure, and then depositing both quartz and ore. The Comstock lode is a deposit at the contact of the diabase with underlying rocks and the ore is likely to continue down with the diabase.

The length of workings in the Comstock is 180 miles. Much timber was required. $174,000,000 silver and $132,000,000 gold have been produced from this mine.

CALIFORNIA GOLD MINES.

Gold was discovered in California in 1848. The gold belt is along the lower slopes of the Sierra Nevada for 700 miles by 20 to 60. The central mass of the Sierra is granite flanked by clay slates, mica schists, chlorite schists, together with quartzites and limestones.

The gold veins run parallel to the strike and stratification. The gold-bearing rocks are largely metamorphic, Triassic and Jurassic, the Carboniferous being the oldest. The placers were derived from these veins.

GOLD PLACERS.

The placers are of two kinds, one distributed by the present river system, called shallow placers. The other by ancient rivers or deep placers. These placers were discovered far above the beds of the present rivers. On the Yuba the gravels are 120 to 250 feet deep and have been protected by flows of lava. These deposits, consisting of all kinds of rocks cemented together, often contain iron pyrites. Some of these placers are found close to the gold veins from which they derived their gold. The lower portion of these placers is of larger boulders than the upper, which is deeply stained with iron by surface waters. The blue gravels are impregnated with pyrite. Fossil wood occurs in a partially carbonized condition. These beds are covered by lava and the wood is often silicified. Gold is generally disseminated, but is found most abundant at "bed-rock." The latter shows groovings by ancient glacial action. After removing gravels scales of gold are seen on the bed-rock. The rock has to be worked up to a depth of 8 or 10 inches. As much as 250 pounds of gold have been taken from 15 square feet. In Tuolumine county under Table Mountain, which is capped with basalt, the formations are similar.

The gangue of the gold vein is quartz and ribboned in structure. Pyrite and cinnabar often occur with gold, also galena. Beneath the line of drainage the ore is undecomposed pyrite. Gold in a cavity is often found in crystals but not so in the compact rock. Opaline quartz occurs in the veins. The walls are smooth and show evidence of much faulting, and deep groovings occur showing a grinding action has occurred between adjoining surfaces from this faulting process.

A remarkable gold vein in California is the "Great Mother Lode," extending from Mount Ophir in Mariposa county to Mokelumne Hill in Calaveras county, over 70 miles. It outcrops as a white wall of quartz from 6 to 60 feet thick. It may be remuneratively productive or not at different points. It is an axis for other veins of the region grouped on either side of it. The quartz veins of California have not been found more subject to impoverishment in depth than others. Many having been worked below 1,500 feet and no increase.

Nevada county produces more gold than any other county in California. Its yield during 1881 being estimated at $3,700,000. In this county there are some important quartz veins and mines, nearly all of which are situated in the neighborhood of Grass Valley, California. The Idaho mine yielded in one year 30,965 ounces in gold. The richest quartz mines of California are those of Bodie district, situated in Mono county. Silliman says Bodie Mountain is one of the highest inhabited points within the limits of the United States. Its summit is 9,500 feet above sea level. Bodie Mountain is an isolated mass of trachytic porphyry. The whole region not long ago was a scene of eruptions.

In Mono lake, twelve miles from Bodie, traces of these ancient fires still exist as is evidenced by the escaping jets of hot vapors and numerous boiling fountains occupying the center of the lake. A close examination of the district leads to the conclusion that Bodie Mountain is an island of eruptive rock about two miles by one mile. The mountain contains some sixteen quartz veins, which on the surface are hard compact uncrystalline chalcedonic quartz, sterile of metal and unpromising for mining explorations. At fifty feet they lose these characteristics, become softer and the quartz more friable. The compact chalcedonic portion, greatly diminished in bulk, forms now a lining upon one, or both sides of the vein, more rarely a seam of varying width in the center of the vein. Horses of adjacent porphyry occur diminishing the vein, which beyond assumes the largest proportions.

The metallic contents which are invisible to the eye are found distributed in dark colored stains, parallel to the surface of the quartz. There is a remarkable absence of metallic sulphurets. Magnetic iron ore is found in minute particles. Blake observes that the Bodie veinstone is formed in layers or coats one over another like sheets of paper with their seams or openings between, which shows that the veins were deposited gradually on the fissures by thermal springs, similar to those at Steamboat.

The "Standard Consolidated" is the principal mine. During the year 1882 the total yield of bullion was $2,084,550, part of it being gold, part silver.

CALIFORNIA QUICKSILVER CINNABAR MINES.

Quicksilver is sold by the flask (an iron bottle so to speak), weighing about fifty pounds and worth about $50 a flask. Quicksilver is cheaper and more abundant than silver, but of course the demand for it is much less, not more perhaps than 2,000 flasks are produced annually.

Its main uses are for mirror backs, thermometers, for the amalgamation of ores and production of vermilion. It has been produced only in a few localities on at all a large scale. These are Almaden, in Spain; Idria, in Austria; Kivei Chan, in China; also in Peru and in California.

Native quicksilver is rare by itself though sometimes scattered through the gangue, it is volatile before the blow pipe. Sometimes it occurs so plentifully in cavities in the rock that it can be ladled up with a tin pail.

The commoner ore from which quicksilver is obtained is cinnabar or mercury sulphide. Its composition is sulphur and mercury. The ore is a brown or reddish color and when scratched by a knife shows a bright metallic red. It much resembles some forms of red oxide of iron or chromate of lead. But the difference is easily found before the heat of the blow-pipe by which it is vaporized.

The old Almaden mine of Spain was worked 415 B. C., yet so far from being exhausted the ore is found to grow richer with depth.

The mines in Idria, Austria, were discovered in 1490 and have so far produced about a million flasks. The mines in China are supposed to be the richest. The California mines at Mine Hill, Santa Clara, were discovered in 1845. The Redington mine of California was discovered in making a cutting for a road. Away from the Pacific slope few deposits are known in North America.

In Almaden in Spain the rocks are silurian and devonian schists, quartzites, and limestones, associated with diabase-tufa, in which the ore occurs. The district is in the Sierra Morena. Pyrite and quartz occur with the ore. There are three tabular masses of ore in the mine, 600 feet by 12 feet thick. The strata of the Almaden mine stand vertically, the veins conformable with the strata. The deposit in which the ore occurs is quartzite intersected by stringers and seams of cinnabar.

The Idria, Austrian deposit, occurs near the contact of quartz porphyry with Triassic sandstone shales, limestone and a breccia or conglomerate. The ore impregnates the porphyry and stringers in the sandstone and shale. The main mass of the ore is in the brecciated conglomerate, associated with calcite quartz and pyrite. The ore came up through a fissure between the contact of porphyry and other rocks. The conglomerate is a "breccia" formed by movements of the strata prior to the deposit of the ore. Cinnabar occurs in rocks of any age, principally in metamorphic schists in granite and eruptive rocks and in post tertiary basalt, also in quartzitic slates, or serpentine and in fact almost all kinds of rocks, especially in regions of great disturbance. It is found too, associated with hot springs and volcanic rocks. It fills crevices in rocks much like other veins, and occurs also in reticulated veins or impregnations. There is no doubt but that it was deposited from solutions or hot volcanic springs, and most likely came up from some deep-seated sources in the granite associated with volcanic phenomena. Cinnabar occurs at the Redington mine in Knoxville district, California, associated with basalt in fissures. At New Idria it is very productive in Cretaceous rocks, associated with eruptive rocks.

In the New Almaden Mine, California, there are some forty miles of galleries. The ore occurs in shattered diorite, diabase, serpentine and sandstone in a gangue of quartz and magnesite. At Steamboat Springs the formations are similar to Sulphur bank. The origin of the ore is there from a double sulphide, and its remote source, as we have said, is probably the granite.

The geology of the coast range in California, in which the cinnabar mostly occurs, consists of granite, overlaid by Tertiary and Cretaceous rocks, some of which are metamorphosed, others not. Serpentine, which is common in the deposits, results from the alteration of schists, or rather of some of the minerals composing the schists, such as augite, feldspar, quartz, etc. These and other metamorphic changes are due to hot solutions, rising from the underlying granite. The igneous massive rocks are granite, diabase, diorite, andesite, rhyolite and basalt.

Before the opening of the Cretaceous the region of the coast ranges was occupied by granite. In the early or first period of the Cretaceous great quantities of sediment derived from granite was deposited on the quicksilver belt, such as sands, shales and limestone. The sea was shallow, with many islands in it. At the close of this first period violent upheavals occurred, folding, crumpling, crushing the rocks, forming the first ranges. Heat caused solution of some of the underlying granite elements, such as magnesia, soda, etc. During the middle Cretaceous a second deposition of detritus occurred. Late in the Cretaceous a great part of the coast range subsided and was under water, the sea reaching to the Sierras. The Chico Cretaceous was deposited. Eruptions occurred at close of Miocene of andesite. It was at this time the solutions of cinnabar occurred. Clear Lake, a cinnabar district, is at the end of a basaltic region, abounding in volcanic caves, borax springs, sulphur, etc. Andesite and basalt eruptions occur, and with them also the cinnabar springs, Sulphur bank and Steamboat Springs. Both cinnabar districts are of the same volcanic nature. At Sulphur bank the ore occurs in the lower portion of decomposed rock. The cinnabar has been deposited from waters containing carbonates, borates, chlorides of sodium, potassium, ammonia, as are now occurring. The ore is deposited in these waters through relief of pressure and the presence of ammonia.

NEVADA.

THE EUREKA MINES, NEVADA.

The geology of this district consists of metamorphic limestones, with traces of stratification lying on quartzite overlain by shale. In these limestones, partly of Cambrian, partly of Silurian age, are irregular chimneys and pockets of ore of galena and carbonate and sulphate of lead—25 per cent. lead and 50 per cent. silver. The Richmond and Eureka consolidated, are both in the southern portion of the district and the most productive.

Throughout this district a great ore channel extends along the eastern base of Prospect Mountain for twelve miles. A contact deposit in limestone, quartzite, shale. Fifty million dollars have been extracted along this deposit belt. The Richmond is down 1,230 feet below the surface. It produced in its first nine years $61,000,000 bullion—33 per cent. is gold and 66 per cent. silver and one ton of lead to every five tons. The ores occur along a zone crushed by movements of the faulted rock on each side. The limestone is filled with fissures along which the ore-bearing solutions have replaced the limestone in large irregular bodies. Cavities occur between the ore and the roof.

UTAH.

The proportion of gold is small in this state and much less than that of silver. The Ontario Mines, near Park

City, are the main producers. The vein is a strong, well-defined fissure vein, running nearly east and west, with a dip to the north from 70° to verticality, traversing a belt of quartzite, cutting through the layers of the formation unconformably, both in dip and strike. On the north or hanging-wall of the vein, is a dyke of gray porphyry 100 feet in width intersecting the bedding of the quartzite, with a general course nearly parallel to the lode. On the east this porphyry approaches closely to the vein, and in some places even forms its wall. Towards the west it diverges, and is separated from the vein by a variable thickness of quartzite.

The lode has been explored by underground workings for 3,000 feet. The deepest point is over 700 feet below the outcrop. The fissure varies from 2 to 20 feet or 4 to 5 feet without faults. The filling is material derived from the walls, being a finely-ground quartzite and clay, from decomposition of the enclosing porphyry. The ore has been deposited in the fissure in a continuous sheet from the surface, as far down as explorations have penetrated, forming a well-defined chute of ore. At the surface this chute had a length of only 500 feet. The fissure, although continuing below the ore body in the east and west is filled with material derived from the walls with little mineral. As this chute was followed in depth it increased in length, until at the sixth level it attained a length of 1,500 feet. Not only has this increased in length as it has been explored in depth, but there has also been a gradual increase in the width of the ore, which in the upper levels averaged only a foot, while on the fifth level it is two to three feet and for considerable distances occupies the whole breadth of the fissure. With this increase in the dimensions of the chute, the ore has become richer as greater depth has been attained.

The first ore worked yielded $70 to $80, while below on the fifth level $125 to $145, and at 700 feet, still higher. Below 400 feet the ore is undecomposed, consisting of argentiferous blende, with quantities of gray copper ore, rich in silver, a little sulphur and iron pyrites. Nearer the surface it is oxidized, the zinc having been removed and the silver occurring as chloride with some native silver and oxidized copper and lead. The gangue forms 35 per cent. of the ore and is of clay and decomposed quartzite.

THE HORN SILVER MINE AT FRISCO, UTAH.

The course of the vein is north and south, its dip is 70°. The lode is from 20 to 150 feet wide. There is a solid body of ore averaging 40 ounces silver to 30 of lead. The ores are horn silver, lead sulphate, arsenic, antimony and ruby silver. The mine was worked to 1,000 feet in depth before they struck water. At the water level the ore changed to galena. The vein also became narrower with depth. It is a contact fissure between limestone and rhyolite. The contact extends three miles, but is only productive at the Horn Silver mine.

In the Bingham and Little Cottonwood cañons, large bedded lead-silver veins are found carrying lead-silver ores above and galena and pyrite at water-level, in Carboniferous limestones resting on underlying quartzites or on the contact between the two. The mines are situated in the Oquirrh and Wahsatch Mountains, south-west of Salt Lake, also south-east of it. The region is disturbed and faulted, porphyry dikes occur, with knobs of granite associated with sedimentaries. The ores occur in belts for considerable distance. In places there are rich chutes or chimneys of oxidized products. In Bingham cañon, a large bed of gold quartz overlies the lead zone, next to the hanging-wall.

In the Tintic district there are three ore belts, from one to three miles long, parallel with the stratification of the vertical blue limestones, but sometimes crossing them. The ore-zone is from 300 to 600 feet wide and bears locally rich chutes of carbonates.

THE CARBONATE MINE.

This is a fissure vein in hornblende-andesite, filled with pebbles from the walls cemented by clay and galena. It is oxidized near the surface. The cave mines here are caves or replacements of limestone by ore connected by small ore channels, more or less filled with limonite and oxidized lead ores. The Utah mines are mostly lead-silver.

The ore is sometimes massive, though the vein shows a banded structure, with seams parallel to the walls. The mine is very wet.

The Ontario was discovered in 1872, and immense quantities of ore have been extracted, averaging $105 per ton.

ARIZONA.

Tombstone lies nine miles from the San Pedro River. The Dragoon Mountains are on the north-east, and the Huachuca Range on the south-west. The country is without timber, and the surface where the mines are opened is in gently rolling ground. Up to 1882 the output amounted to $7,359,200. In going from Benson to the mines, post-pliocene deposits rise to a granite plateau, which may be eruptive. At Tombstone this is overlaid by stratified deposits of quartzites, limestones and slates, frequently repeated, dipping eastward at a low angle. The strata is Paleozoic, some of it Lower Carboniferous.

Intrusive porphyry dikes cut through the strata, following the general line of faulting of the country, also of the mineral veins. Iron pyrites is disseminated through the layers of Paleozoic quartzite. The beds above are of dark argillaceous shale, alternating with black siliceous shale. In the black limestones are the chief repositories of bedded masses of rich silver ore. The whole series of beds in this central part are thrown into folds, being regularly folded in a series of wave-like flexures, traceable on the surface.

The chief ore-bearing vein is the Grand Central, upon a dyke of diorite-porphyry, carrying ore in, through, and alongside it. The dyke is laminated and penetrated by thin veins of quartz. It is also mineralized by iron pyrites in cubic crystals, which have dissolved out, leaving cavities of spongy porphyry. Although mines have been worked to a depth of 600 feet, there are twelve to fifteen miles of drifts, levels and winzes, yet the undecomposed ore below water-level has not yet been reached. The surface ores are much charged with red oxide of iron. There has been much kaolinization of the porphyry. Gold and silver occur in a free state together with pyrite and galena. The silver is in the form of chloride and iodide. The average value of the gold and silver in 1880 was $70, gold representing 20 to 25 per cent., the remainder being silver.

Gold is in thin flakes in, and along thin seams and and cracks in the mass of the rock, as if it had infiltrated in from solution. The whole of the dyke together with adjoining strata has been subjected to extensive movements and displacements, shown by brecciated cross-courses and by seams traversing both igneous and stratified rocks. This disruption of the dyke with its attendant fracturing and brecciation of the country rock, accompanied by the movement of the dyke upon itself and the formation of heavy clay seams, has provided suitable places for the accumulation of ore, generally found in the softer and more broken portions of the dyke. Bedded ore deposits are associated with bedded dykes and vertical fissures, nearly parallel with the Contention lode. The long West side lode is traced two miles till it passes into underlying granite. The ores in the Tough-Nut are a replacement of limestone, and are bedded, and as at Leadville form cavernous deposits. These deposits follow the planes of stratification, then break across it vertically, following a crack, then expand horizontally and enter another crack, when they drop down by a series of steps from one layer to another between the limestones. The ores in these bedded deposits in limestone are more full of lead than in the eruptive feldspathic dyke. Galena, blende and iron pyrites are abundant in masses, which, within reach of the oxidizing agents, are converted into oxides and carbonates.

The Castle Dome district lies in the foothills on the west slope of a range in Arizona on the Colorado river. The district is two miles by seven, following the trend of the mountains. Lodes were discovered 1863. The ore is a dense brilliant galena carrying 30 ounces silver. The rocks are mica schists and clay slates standing vertical, traversed by porphyry dykes, bearing close relation to the mineralization of veins. The course of veins is north-west by south-east.

ARIZONA COPPER MINES.

Oxidized copper occurs in Carboniferous limestone associated with eruptive rocks. Veins also occur in eruptive rocks only, or in sandstone in the south-east of the State in the Black Range.

At Clifton, the mining district lies in a basin surrounded by hills of carboniferous limestone, resting on sandstone, and that on granite. In the center of this basin is a huge eruptive porphyry, with large inclusions of limestones. Eruptive felsitic dykes abound, and an outflow of late trachyte. The ores are in limestones. The ores appear to have originated along fissures, from which they were afterwards dissolved out into irregular cavities, or else along the contact between dykes and limestones, or in blanket deposits in limestone in contact with intrusive porphyry sheets, much as the lead ore deposits occur at Leadville, Colo. The ore is at times a copper wad. In the limestones it is oxidized. Great bodies of clay are associated with the ores. Ore is 15 per cent. copper.

The ores that occur in the porphyries are generally in the form of narrow stringers above, joining a single vein below, or else a fissure vein in a porphyry dyke. Chalcocite passes down into chalcopyrite. The ores in the granite are chalcocite in fissure veins. The ores in the limestones are the most productive.

At Bisbee the ores are oxidizcd and deposited along planes and points of carboniferous limestone, which has been replaced by ore by "metasomatic" substitution, as at Leadville. Porphyry is associated with these ore deposits. The fissure veins that occur in sandstone produce an antimonial copper. Veins also occur in a talcose slate, filled by quartz gangue and carbonate of coppər.

Numerous veinlets form a "stockworke" in the gneiss and near dykes of diorite and other eruptive rocks, but they are too low grade to work. Beds of chrysocolla (silicate of copper) are found just below the surface in superficial "wash" derived from leaching from the stock-workes above.

At Santa Rita, native copper occurs, changing into cuprite above. Pellets of copper occur in the eruptive felsite.

In the Black range, contact deposits of oxidized ores above, pass down with depth into sulphides. They are found in slates at the contact with porphyry dikes. Carboniferous limestones occur near by, pierced by eruptive dykes, but no ore is found in them.

The presence of eruptive rocks associated with these ore deposits, as elsewhere in mining districts, is noticeable. They were directly or indirectly the means of circulating copper-bearing solutions after the deposition of the Carboniferous limestones. The contact ore deposits were the result of replacement.

Arizona began its copper industry in 1873-80. Copper seems liberally dispensed through this State, the main obstacle is the lack of fuel. Coke, for instance, costs, delivered, from $20 to $40 per ton. The ores are mostly oxides, but the quality of the copper is good. As observed, the main bodies are in Carboniferous limestone. The assay at this mine is from 8 to 20 per cent. copper. With depth the deposits become shallower and pass from oxides into sulphides. The Copper Queen is a large producer, yielding some 5,000 tons a year.

ORE DEPOSITS AROUND PRESCOTT, ARIZONA.

Some years ago I visited some of the mines around Prescott which were at that time only in a state of prospect.

The characteristics of this part of the country are table lands of mesozoic strata, with many overflows of dolerite and other eruptive rocks, elsewhere there are granitic mountains more or less capped with volcanic rock or traversed by volcanic dykes. The aspect of the region is generally very sterile and water is scarce. From Prescott Junction down the Sullivan cañon to Prescott City lava predominates for awhile, but with the deepening of the cañon shows slates, schists and quartzites underlying it. They are probably of paleozoic age. These are thrown into a series of contortions and folds. About six miles from Prescott at "Point of Rocks" we come to the first outliers of massive granite capped with lava. The altitude of Prescott is about 6,000 feet above sea level, and at Xmas was as warm as summer. A display of the ores in a store in the town shows their character to be refractory, and to consist mainly of coarse and fine-grained galena in limestone or quartz, with honeycombed surface quartz showing free gold. Zinc also occurs and some native silver. A region some distance from Prescott produces large quantities of copper. In the Black range and limestone district the ores are mostly in pockets in the limestone, or in quartz veins in eruptive rocks. Some of the mines were shipping a little to the Colorado smelters, but most of them were awaiting the advent of a railway. Reduction works were talked of, but the distance of fifty miles to Gallup for coal, and that not a coking coal, were obstacles. The limestone around town was too siliceous for a flux, but a certain amount of iron could be obtained from the surface outcrops of the veins.

Several of the mines are along Haciampa Creek. The hills are granitic, traversed by dykes of syenite, diorite, etc. Some sluice mining for gold is done along the bed of the creek, where the placer materials are cemented into a hard rusty conglomerate. The placers are not generally deep, and "bed rock" is soon attained. Ruins of abandoned stamp mills occur. It was claimed that from some of the gold mines they had stamped ore running $128 per ton. The Haciampa forms a moderately deep and narrow cañon, and is at seasons a violent stream, though in summer the water is rarely more than a foot deep. After passing through a narrow gorge the stream debouches into an open valley. The hills rise between 1,000 and 2,000 feet above the creek. The country rock is mainly granite and syenite, traversed by diorite and other eruptive rocks. Some of these eruptive dykes are mineralized and constitute the veins. In other cases large, hard, quartz veins traverse the country in a north-east and south-west direction and carry the ore. The dip of these veins is 75° to 80°, and the veins are generally parallel. Some of the diorite dykes appeared to be altered to a granulitic quartzoze material, and this again is intersected by small veinlets of pure or rusty quartz, which generally carry the ore. In the same material are numerous rusty, clay and iron seams, in cracks in the rocks. The country seems generally to be a good deal shattered. There are not well-defined walls to these altered dykes and seams, the walls, such as they are, are little more than lines of cleavage, which may be found at intervals of every few feet. It is probable that a certain amount of gold is distributed throughout the entire hill. In the Lion and Tiger property two parallel veins occur, each about one hundred feet wide and one hundred feet apart, running from top to bottom of the mountain sloping to the river.

Running through the north end of the Lion a dyke of dark eruptive rock is found, forming approximately the foot-wall of this gold outcrop. The dyke is altered to a granulitic substance, through which traverse small veins of quartz, which appear to be the main ore carriers, rather than the porphyry, which assays showed to be nearly barren. With depth these veins of oxidized ore will pass into unoxidized pyrites as is shown in one of the tunnels and as might be inferred from the amount of "copperas" or sulphate of iron on the outcrop. These pyrites however, show by assay to be fairly rich in gold and would pay for roasting. There is a good deal of shallow surface oxidized ore over a considerable area which will pay well in free-milling free gold, as long as the crust lasts. The average of the ore is from 25 to 30 dollars a ton. At the time of our visit they were working the ore only by a small "arastra" on picked specimens.

BRITISH COLUMBIA.

KOOTANIE DISTRICT (G. M. DAWSON).

Within the last three or four years numerous discoveries of valuable ores have been made in the West Kootanie district. This district is rugged and mountainous, comprising the south portion of the Selkirk range and the Columbia or gold range. Between these ranges are a string of lakes such as Arrow and Kootanie lake. The ranges are not very continuous. The rocks are mainly massive granite, also in places stratified rocks overlie the granite. The average height of these ranges is from 8,000 to 9,000 feet above the sea. The country is densely wooded.

Two remarkable long and deep valleys traverse the district north and south, one occupied by the Columbia river and Arrow lake, the other by the Kootanie lakes. The valleys are connected by a transverse valley containing the west arm of the Kootanie lake and part of the Kootanie river by which the lake discharges into the Columbia.

GEOLOGY.

The oldest stratified rocks are mica-schists and gneisses, also some coarsely crystalline marbles. The gneisses sometimes pass into quartzites, especially near the marbles. The rocks are of Archæan age.

Overlying these at Hot Springs are grey and green schists, the latter a diabase schist. This series may be unconformable and newer than the Archæan. Over these are massive gray limestones, sometimes changed into white marble, below this is a conglomerate. The green schists are composed of volcanic material made schistose by pressure. The thickness of the whole series is 32,000 feet.

Most of West Kootanie consists of massive granite or granitic rock with numerous dykes. Some of the granites are hornblendic and porphyritic. They are of intrusive origin and of later date than the stratified beds, as the latter are altered by their contact. They are intimately connected with metalliferous veins in stratified rocks, which were deposited at the time of their intrusion.

Granites of the recent class occur as dykes cutting through grey granites, their color is pinkish. With the exception of the Poorman mine and one or two others, all mines are in the stratified rocks. Exceptional veins traverse a hard, dark gray, mica syenite, and are gold-bearing, associated with iron pyrites in quartz. Those in stratified rocks carry galena, blende, pyrite and are low grade in silver, of such are the Hendryx and Hot Springs mines. The richer ores at Hot Springs are in green and grey schists and limestones. The richness is due to the influence of the country rock and to proximity to granite.

The area of stratified rocks in which the ore deposits of Toad Mountain occur are surrounded with granite. The alteration of the rock is due to the heat of the granite. The "country" rock consists then of altered volcanic material of perhaps Paleozoic age and is derived from the detritus of a diabase porphyrite. A greenish-gray rock, with coarse porphyritic crystals of plagioclase and pyroxene, are very characteristic.

The occurrence of these ores in green, altered volcanic rocks shows that these rocks may become a metalliferous series when other conditions are favorable. Those conditions may be fissures segregating minerals.

MINES.

The Spokane mine near Hot Springs occurs near a wide belt of quartz and a dyke of augite-andesite. In the vicinity of "Number One" mine the rock is limestone, the direction of the veins is north and south, cutting across stratified rocks. Some of the lodes can be traced for miles. The lowest tier of deposits in the mica schists yields 20 to 40 ounces silver, while further up selected ores yielded 80 to 300 ounces. The richest deposits are in limestones and black argillites. The ore is principally argentiferous galena, decomposed in the limestones to carbonates for some depth, also native silver and grey copper. The ore occurs in irregular pockets and impregnates the limestone as at Leadville, Colorado, or in shattered rock. Numbers of deposits are found and some ores are rich in silver. The ore deposits on the Hendryx peninsula are low grade, from 15 to 40 ounces silver, but the ore deposits are large.

On Toad Mountain the ore deposits are confined to isolated areas of stratified rocks, eleven miles by two, surrounded by grey granites.

ORE DEPOSITS OF WASHINGTON.

Comparatively little is known of the geology of this State. The following is from a letter to the author by Mr. C. E. Bogardus, assayer and chemist in Seattle.

"The country is in a state of prospect; what mines will show, remains to be proven. Some prospecting has been done in this State for years, but the interest and real prospecting began in 1890, continuing up to the present. The prospecting has been mainly in gulches, it being so hard to get over the mountains where there is no trail. There are miles and miles here that no man has ever been over. Our fir and pine forests are like an African jungle and the mountains are very precipitous. The trees are large and close together, this, with a heavy undergrowth and fallen logs lying criss-cross, make traveling hard and slow and no ledges can be found only where nature has opened them up by her mountain streams. As the country gets roads and is cleared, everything will improve.

Though but little has been deeply mined we have the surface indications of very large quantities of ore. We have found in ledges large enough to work, gold, silver, lead, copper, antimony, iron, also of economic value, coal, asbestos, onyx, lime, pure quartz ledges for glass, fire-clay, potters' clay, kaolin, etc.

Our State is mineralized nearly the entire length of the Cascade Mountains, but as far as present knowledge goes, it begins more truly at the Sooqualmie Pass and runs north to the boundary and extends down into the foothills on both sides. In the northern part of the State the mineral belt extends from the mountains, east to Idaho Territory. A 240-ton smelter is now under construction by owners of the Monte Cristo district. They have considerable work done and expect to ship about the middle of the summer at Everett, Washington."

"There are between twenty and twenty-five mining districts now in the State and new ones being found. But to give us an idea without too much detail I shall divide it into sections of the State.

Beginning in the north-east corner we have large deposits of galena, good sized ledges, but low in silver, from 10 to 20 ounces. They carry some zinc, not as sphalerite by itself, but thoroughly combined with the lead.

Coming west is the Reservation which is reported to be a gold country, but nothing is as yet known of it. Then in Okanogan county we have a variety of ore in the north part. There is free-milling gold and galena and a strip of rich chlorides. The chlorides are in a limestone belt. Gold occurs in slate and porphyry. This is about the center of the country.

West of Kanogan district we have the lake St. Lelar, Bridge Creek, Horseshoe Basin, all in a group. They are silver camps carrying galena, pyrargyrite, etc., in granite and porphyry. South is a gold district in schists. In the Besleslin, Niger Creek and Swark districts free gold occurs in quartz and talc with pyrites, both arsenical and chalcopyrite. The chalco pyrite is very rich in gold. A 40-stamp is nearly completed in the Beslaslin district. The veins are large or else the ore occurs in pockets. The average is not high grade. These districts are about ten miles south from The Northern Railroad.

Coming across the mountains is the Stroqualmie district, about seventy miles from Seattle. It has some high grade galena and copper. The walls of the veins are granite and quartzite and some porphyry. Going north we have a series of ore belts of much the same kind of ores, viz, galena, in porphyry and quartz with pyrite and sphalerite mixed, carrying also a little gold and some bornite. The walls are granite or syenite and quartzite, with some porphyry. The veins are contacts.

Silverheel, Elk Bed, Stilagaumish, Monte Christo, are all grouped together. The Great Northern Railroad goes ten miles south of Silverheels district. Silver Creek empties into the north fork of Skykomish river. Monte Christo, at the head of Sauk, Sillagaumish district, is at the head of a river by that name. The railroad now building passes up this river, and will tap the last two districts named. At the head of the Cascade River is the Cascade district. This is just across the Divide from Horseshoe Basin. The formation of ore is about the same as that in the southern part of the State. Some good galena has been found, and some gold, but nothing very definite is known. In the Olympia some copper is found, but not much attention has as yet been given them. They are hard to get around to.

Our coal is a lignite, also bituminous. We have several veins of coal working in the Skagit and some east of Seattle, one at Loslyn near Ellensburgh, east of the mountains.

Iron ore (hematite) magnetite, large deposits of this occur on the Skagit river and near Inoqualmie Pass, on both sides of the mountains. Large deposits of onyx occur at Hematchee and Pomeroy.

Asbestos occurs in large deposits, brittle and of short fiber, the beds are four to six feet thick. Fire-clays are associated with our coal seams. Lime comes from large deposits on Puget Sound, San Juan and Orcas islands.

Our iron we are counting on to give us a large industry, having the limestone and good coking coal and the iron ore in large quantities. Our State is badly broken up, the strata dips at all angles and many large slides occur. The majority *of our ores are low grade.*

Alaska Ore Deposits.

NOTES ON THE TREADWELL MINE.

H. P. CUSHING, A. M., B. S., F. G. S. A.

In the month of June, 1890, the writer had the privilege of spending two hours examining the Treadwell mine, and of half an hour's conversation with the superintendent, Mr. Calderwood, while the Alaskan steamer, on which he was a passenger, was making a stop of three hours at that point. The length of time spent there hardly warrants him in attempting to speak dogmatically concerning the mine, or in the attempt to give a full description. The few brief notes gathered, however, may not be without interest.

The greater portion of Alaska is totally unexplored and unknown. Southern Alaska, that narrow strip lying between Canadian territory and the Pacific Ocean, and extending in a north-westerly direction from Dixon entrance to Yakutat Bay, is the best known. That portion of this strip lying beyond Cross Sound is occupied by the lofty mountains of the St. Elias and Fairweather ranges. South of Cross Sound, however, the mountains are much lower, and all the deeper valleys extend below sea level. As a result, a complex series of narrow salt water channels penetrate the land, either completely separating considerable portions of it from the main land as a series of large islands, or else extending back into the main land itselt for many miles as fjords, Glacier Bay, Lynn canal and Taku inlet furnishing magnificent examples. These water channels have been fairly well explored, but even here little is known of the land back a short distance from the water. The mountains rise precipitously from the water and their slopes are very densely covered with vegetation. Exploration and prospecting are, consequently, extremely difficult matters. In time to come, however, when the forests have been cleared away, valuable metalliferous deposits are sure to be found.

The geological structure of this region is exceedingly complicated, due to the disturbances which have taken place. There has certainly been two different periods of crust movements here, and probably more. The original shales and limestones have been shattered, fissured, faulted and metamorphosed, and at certainly two different periods of time, probably more, outflows of eruptive rock have taken place. Great numbers of these fissures have been filled with metalliferous matter. Small veins abound, carrying gold-bearing pyrites, generally in a quartz gangue, or silver-bearing galena and silver sulphurets, generally in a calcite gangue. These veins are found both in the metamorphic slates and limestones, and in the eruptive rocks. In the large majority of cases the deposits are of no value whatever, due to their small size and the prevalent leanness of the ores. When they seem to hold out promise for the future it is more often from the size of the deposit than from its richness.

The town of Juneau is the headquarters of the Alaskan mining industry. The most available passes for getting into the Yukon Basin, head near Juneau, so that prospectors bound for the former region fit out in Juneau. Moreover, in the vicinity is the most prosperous mining district of Southern Alaska. Juneau lies in a little cove on the shore of Gastineau channel, surrounded by steep and rather high mountains. The rainfall there is enormous, over 100 inches a year. This narrow channel separates it from the large island called Douglas Island. On Douglas Island, directly across from Juneau, the Treadwell mine is situated on an ore deposit prominent among all Alaskan deposits yet discovered, and possessing characteristics which would make it a notable mine anywhere. The deposit worked is of enormous size, whose outcrop strikes something to the west of north, nearly parallel to the shore of the island. The extent of the outcrop I do not know, but it has been traced for a great distance. As far as the workings have extended the two walls of the vein are nearly parallel, the vein holding its width as the workings descend. The walls dip away from the water or toward the west, at an angle of 75°. The country rock on both sides of the vein is a kind of metamorphic slate, whose exact character and composition has not yet been investigated. The Treadwell claim extends along the vein for a distance of from 7,000 to 8,000 feet. Near the middle of the Treadwell claim the widest part of the vein is found, it having here the enormous width of 600 feet. It narrows rapidly to the south, more slowly toward the north, so that on the Alta claim, south of the Treadwell, the vein is comparatively narrow, while on the Bear's Nest claim to the north it is still very wide. In the more southerly part of the Treadwell the width is about 100 feet.

The shores of Douglas Island rise quite steep from the water. At the point on the Treadwell claim where the work is going on at present, the foot-wall of the vein reaches the surface at an elevation of 160 feet above the water. The width of the vein here is about 150 feet, and the surface outcrop of the hanging-wall has an elevation of 240 feet. This is near the south end of the claim, and also near the company's stamp-mill. In the summer of 1890 the excavation made in the vein at this point had reached a depth of eighty feet, as measured from the surface outcrop of the foot-wall. Formerly the outcrop of the vein, due to its great hardness as compared with the enclosing slates, rose up in a peak of considerable size, at a point on the vein somewhat north of the present workings. The summit of this quartz peak reached a height of 800 feet, nearly 600 feet higher than the outcrop of the hanging-wall at the present workings. I believe that the rise in this outcrop between the two points is not very considerable. The first mining done was the simple working off of this peak. At the present workings a shaft was run down the foot-wall, and by means of it two deep pits excavated, running the full width of the vein. A tunnel has been run into the mountain side with the stamp-mill as a starting point, which cuts the vein underneath both these pits, and about twenty feet below their present floors, with openings from the tunnel into the pits, down which the ore is dumped into cars below the tunnel. The present workings consist in extending these pits along the vein without deepening them. The amount of ore already taken out is vast, but there still remains an enormous amount to be removed before any deepening of the workings will be necessary.

The gangue is for the most part quartz, a white, transparent quartz which has been considerably crushed and thereby rendered granular and opaque. A peculiar greenish-looking rock of unknown character is also found, but forms only a small per cent. of the gangue. It is much poorer in gold than the quartz. Through the entire gangue, quartz and green rock, pyrite is evenly but somewhat sparingly distributed in small, rather well crystallized individuals. Occasional streaks of quartz, nearly free from pyrite occur, and at times pyrite alone makes a considerable part of the mass. Rarely, horses of slate have been met with, one of which was of great bulk. These were taken out along with the ore and sent through the mill as the easiest way of getting rid of them, as was also a large mass of slate from the hanging-wall which fell into one of the pits. The quartz carries a small amount of free gold, but the main portion of gold is enclosed by pyrite and cannot be amalgamated. Occasional small streaks of molybdenite have been found on the west, or hanging-wall, and these run high in gold.

The Treadwell mine is an admirable example of an ore body in which the content of the precious metals is very low, and yet the property is a very good paying one, on account of the vastness of the deposit, and the ease and cheapness with which it is worked. It lies only a few steps from the water. With steamship navigation, abundant water-power down the mountain side is at hand and utilized, and seemingly inexhaustible fuel is growing thick on the mountains all around. The ore carries on an average of $3.60 of gold to the ton, and nearly the entire assay value is saved. The average cost of making it is $1.60 a ton. Six hundred tons of ore are pulverized daily by the 240 stamps in the company's enormous stamp-mill. After passing through Blake crushers and the stamps the ore is run over separators where the pyrite is separated from the quartz and the free gold is amalgamated. The pyrite is then roasted with salt and afterwards chlorinized. The treatment is inexpensive and saves nearly the full assay value. The ore carries no silver. During the summer the mill is run by water-power, but during the long Alaskan winter a resort to steam is of course necessary.

The Alta Mine, south of the Treadwell, is working in the same ore, but owing to the increasing narrowness of the vein as their claim is approached, the scale on which work is carried on cannot begin to approach that on the Treadwell in magnitude. The Treadwell is separated from the Bear's Nest claim, to the north, by a great mass of slate, which is probably an enormous slate "horse." Curiously, the character of the ore meets with an abrupt change at the point where this slate is interposed. The Bear's Nest claim is on the same vein, the vein has there great width, the ore has the same appearance exactly as on the Treadwell, but there is a sudden, sharp falling off in the amount of contained gold, so that the claim is practically worthless. Former placers were worked on the site of the Treadwell, and yielded fair results. None were found on the Bear's Nest. A number of sacks full of Treadwell ore, which were carried over to and impartially distributed over the Bear's Nest claim, were very influential in producing its sale for a good price. A certain amount of chloride of gold, judiciously sprinkled round, was an important adjunct in effecting the sale.

"Silver Bow Basin is four miles from Juneau, and is the best gold placer district in Alaska. The ore runs from $40 to $100 per ton. Although gold occurs in numbers of places the grade is either so poor as to admit of handling by wealthy corporations only, or the placer grounds are so situated that the expense of handling is too great to admit of profit. Alaska is no place for a man without means. As soon as capitalists take hold of the immense deposits of low grade ore the territory will come to the front as one of the chief gold-producing countries. Copper is found in a few localities. Indians occasionally bring in large chunks of native copper, but keep the location secret."—*W. B. Stevens, in Colorado School of Mines Scientific Quarterly.*

MONTANA (COPPER MINES), BUTTE.

The veins occur in fissures, which have been greatly enlarged by ore replacements, filled with copper sulphide, bornite, etc., in a siliceous gangue. Some silver is with the copper. Large rhyolite dykes occur in the vicinity of the veins. The principal country rocks are dark and light granites. In these are the fissure veins. Two series of veins occur in the darker granites, one copper-bearing, the other silver. The silver veins are destitute of copper.

The parallel copper fissures have been worked for a distance of three miles. The ore bodies are from ten to 150 feet wide. At the surface the ores are oxides and purple ore, running from 10 to 50 per cent. copper. With depth these pass into sulphides, running only 5 to 10 per cent. in copper, but also carrying silver. The celebrated Anaconda started as a silver mine, but copper was struck at a depth of 400 feet in the form of oxides, which deeper became sulphides. The latter are treated by concentration, the matte assays from 35 to 70 per cent. copper. It is shipped East and worked into ingots.

In 1891 Montana produced $56,000. The ores are said to be richer than at Lake Superior, but inferior for making wire.

The Granite Mountain silver mine, at Phillipsburg, Montana, occurs in a vein in granite, standing vertical and striking east and west. The vein is three to six feet. A good deal of ruby silver is found in this mine, greatly enriching the product. This mine has paid $11,000,000 to its stockholders, and continues to produce $100,000 monthly. The ore mills from $60 to $150 per ton.

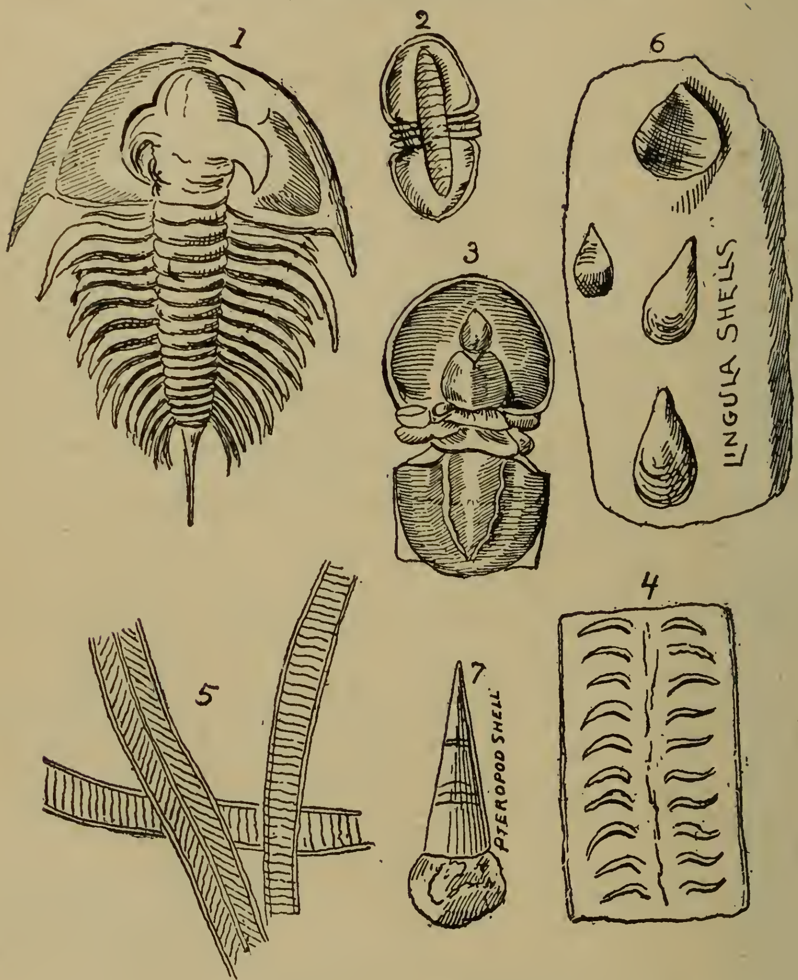
CHARACTERISTIC

		ROCKS	MINERALS METALS &c.	FOSSILS
Psychozoic	Recent	Soil, Clay, Pebbles	Some Gold	Man, Buffalo &c
Cenozoic	Quaternary	Pebbles, Sand, Clays	Placer Gold	Elephants teeth, Bones, Man Bones, Tools,
	Tertiary: Pliocene	Loosely Stratified Conglomerates Sands	Old Gold placers in California	
	Tertiary: Miocene	Basalt Andesite Rhyolite Lavas Conglomerates Sandstones	Lava-Gold & Silver bearing Thin Lignite Coal Metamorphosed Sandstones Gold Bearing in California	Fossil Leaves Mammals
	Tertiary: Eocene	Shales & Clays Some of Volcanic detritus, Others of Granitic detritus	also Ashphalt in Colorado and Cala.	In California Marine Shells
Mesozoic	Cretaceous: Laramie	Clay Coal beds Sandstones	Coal	Leaves, trees &c. Sea Shells
	Cretaceous: Colo	Drab. shales. clays Limestone Dark shales	Canon City Oil horizon Flux Lime Clay, Iron, Stone	Scaphites, Baculites Sea Shells Inoceramus Oysters
	Cretaceous: Dakota	Conglomerate. Sandstone	Fire Clay	Leaves of trees
	Jurassic	Variegated Clays Red marls. sandstone Limestone	Gypsum Oil & Lime & Red Building Stone	Dinosaurs. Colo. Sea Shells in Wyoming
	Triassic	Thin Lime Stones Thick Red Conglomorate Sandstone	Copper. Silica for Glass Silver. Reef Sandstone Some Red Building Stone	Foot prints of Saurians
Paleozoic	Carboniferous	Gypsiferous Shales Reddish Conglomerate Eastern Coal Beds Shales, Sandstones Grits & Shales	Eastern Coal of Pennsylvania	Land plants
	L. Carb.	Blue Limestone	Silver, Lead,	Corals Sea Shells, Spirifers, etc
	Devonian	Reddish Sandstone Lime stones	Eureka. Nevada Silver, Lead Deposits	Sea Shells Fish Corals
	Silurian	Drab pale Limestone Dolomite	Marble Silver, Lead Iron	Sea Shells Crustacea Trilobites Corals
	Cambrian	Slates Quartzites	Gold	Sea Shells
Archæan	PreCambr	Quartzites, Conglomeritic Gneiss, Schist Slates, Marble	Gold, Silver, Lead, Zinc, Copper, &c Iron	Few Positive Signs of life
	Archæan	GRANITE, GNEISS Schist, Syenite		

PROSPECTOR'S GEOLOGICAL TABLE OF WESTERN FORMATIONS. SHOWING PRINCIPAL CHARACTERISTIC ROCKS, MINERALS AND FOSSILS TO BE FOUND IN THEM.

PLATE XXI.

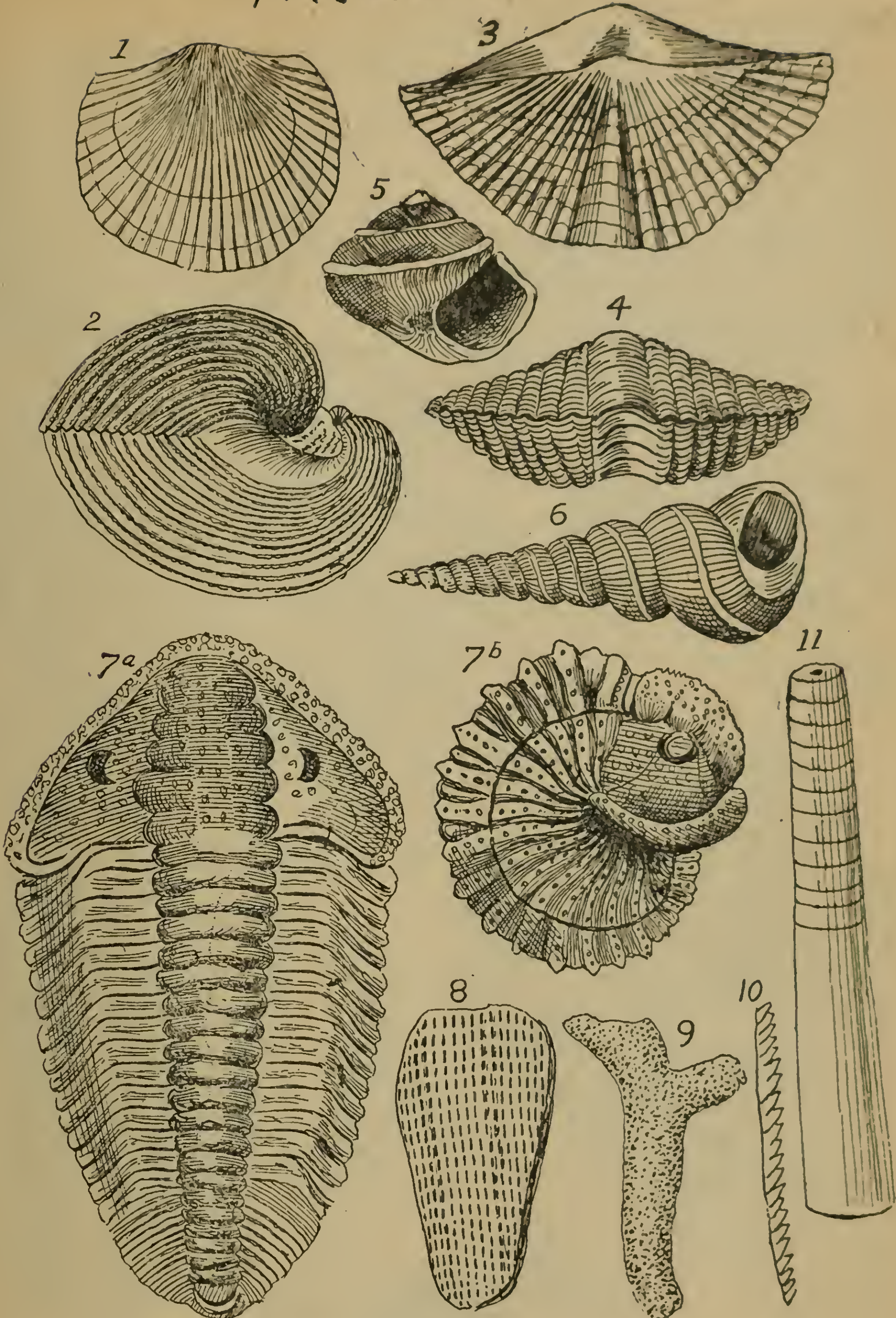
PALÆOZOIC



CAMBRIAN FOSSILS
1, 2, 3 TRILOBITES. 4, TRACK OF CRUSTACEA
5, TRACK OF WORM 6, 7, SEA SHELLS

PLATE XXII.

PALÆOZOIC

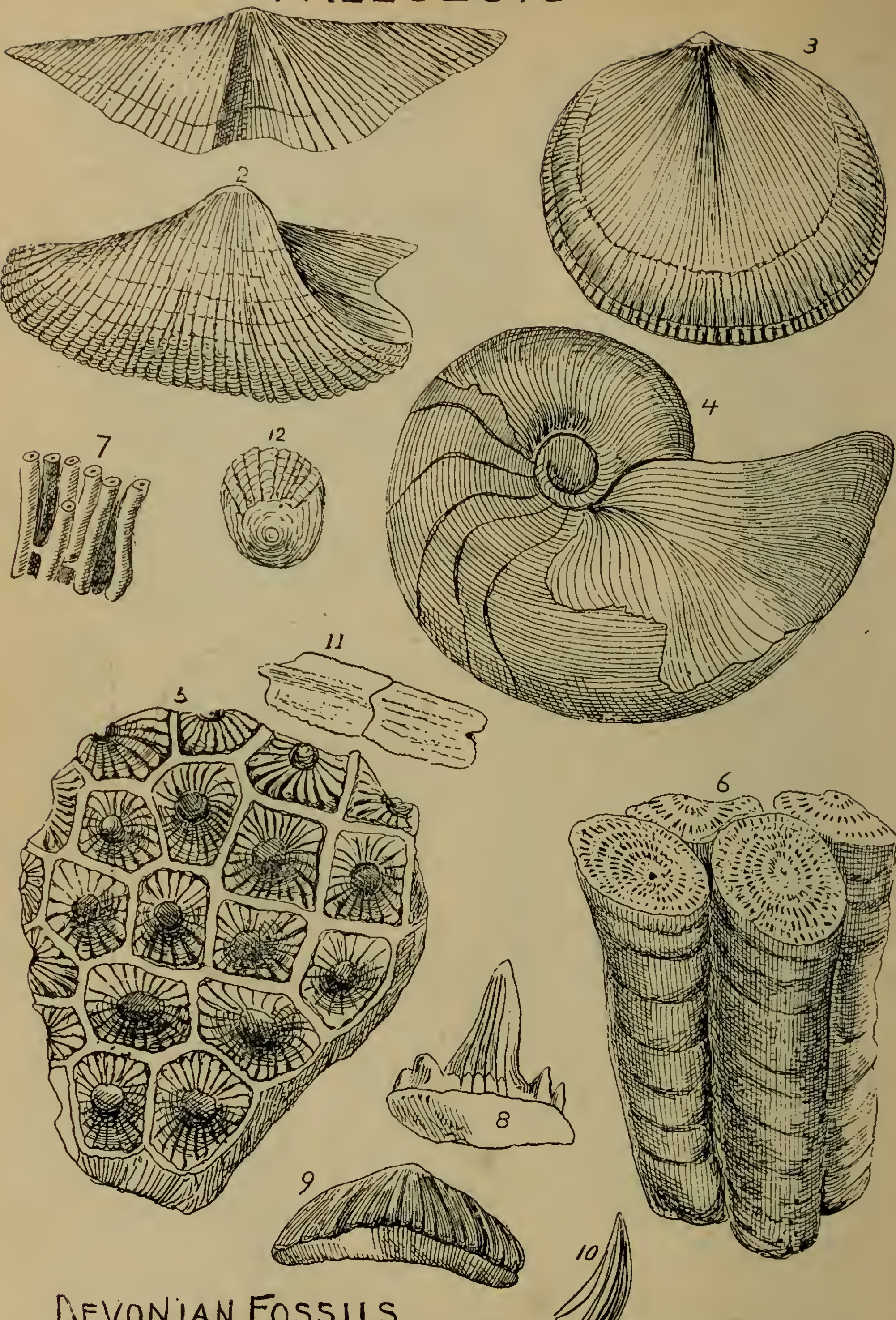


SILURIAN FOSSILS

1.2. Orthis. 3,4, Spirifer. 5, Pleurotomaria. 6, Murchisonia. 7 a–b, Trilobite (Calymene). 8, Coral Fenestella. 9, Coral Chœtites 10 Graptolite 11, Orthoceratite

PLATE XXIII.

PALEOZOIC



DEVONIAN FOSSILS

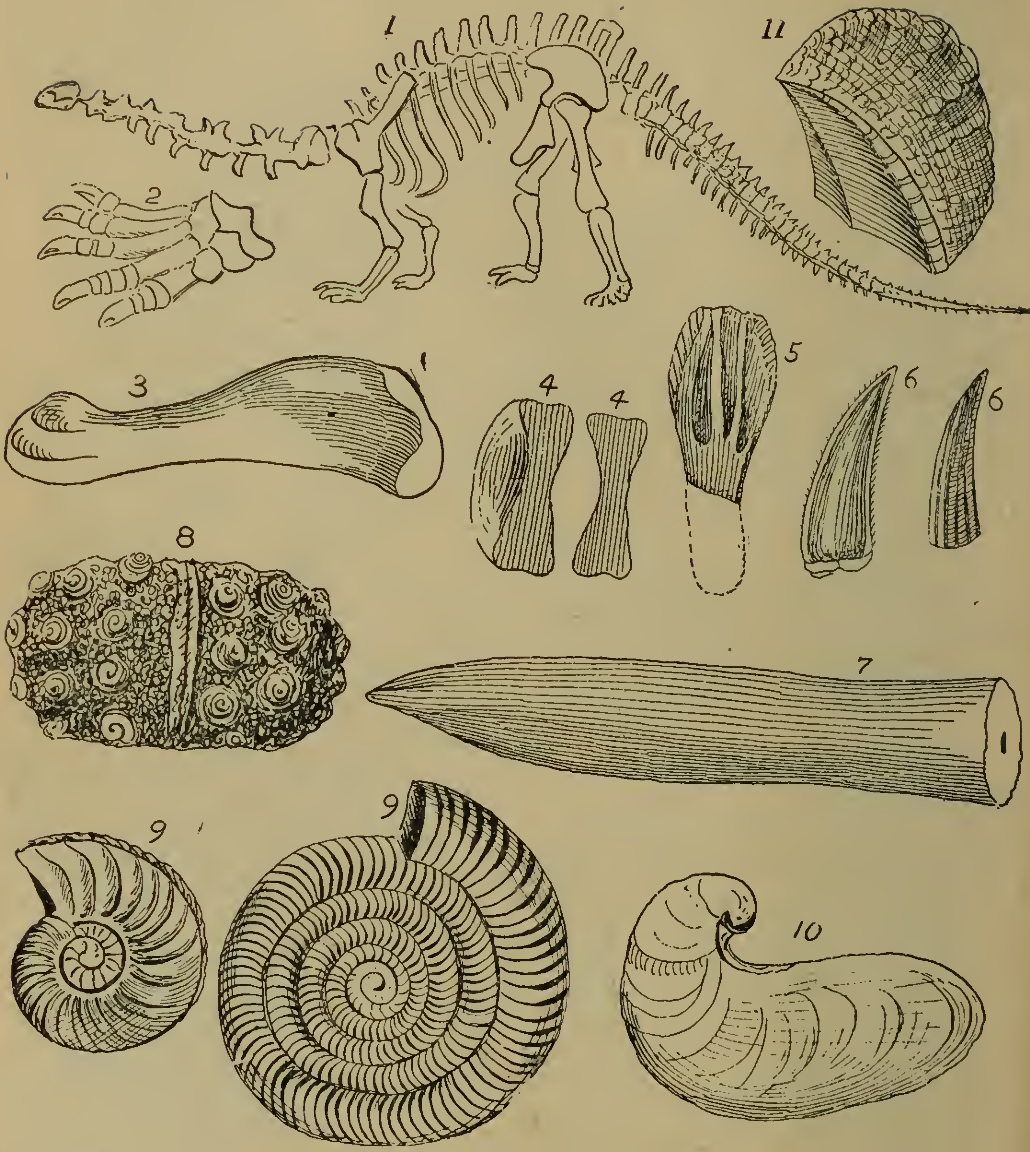
1 SPIRIFER 2 COMOCARDIUM 3 ORTHIS 4 GOMATITES. 5, 6. CORALS
7. 8. 9. 10, FISH TEETH 11. 12 FISH SCALES

PLATE XXIV.

1a, b, c, Productus. 2, 2, Spirifers. 3, 3, 3, Rhynconella. 4 Euomphalus. 5, 5, Crinoids. 6, Pleurotomaria. 7, Bellerophon. 8, Athyris Subtilita. 9, Astartella. 10, Goniatites. 11, 12, Corals. 13, 14, 15, 16, Plants. 17, Spine of Echinus

PLATE XXV.

MESOZOIC FOSSILS
JURA-TRIAS.



1, DINOSAUR LIZARD. 2, 3, FOOT AND SHOULDER BONE. 5, 6, 6, TEETH OF SAURIANS. 4, 4, VERTEBRA OF SEA SAURIAN, ICTHYOSAURUS
7, BELEMNITE. 8 ECHINUS 9, 9, AMMONITES. 10, EXOGYRA 11 TRIGONIA SHELL

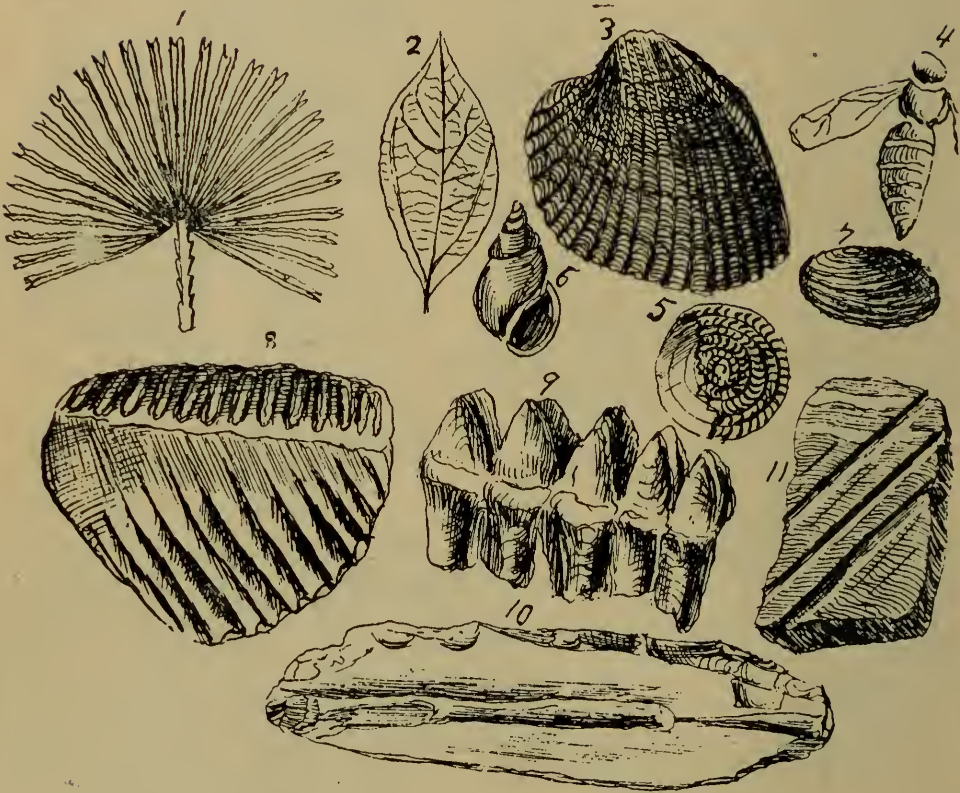
PLATE XXVI.

CRETACEOUS

1, 1, INOCERAMUS. 2, CARDIUM. 3, CORBULA 4, MACTRA. 5, MARGARITA. 6 FASCIOLARIA. 7, ANCHURA 8, PYRIFUSUS. 9, 10, SCAPHITES. 11, CRIOCERAS 12, BACULITES 13, SHARK'S TOOTH.

PLATE XXVII.

CENOZOIC FOSSILS
TERTIARY AND QUATERNARY



TERTIARY.

No 1. PALMETTO. 2 CINNAMON LEAF. 3 CARDIUM. 4. INSECT 5 HUMMULITE SHELL. 6.7. FRESH WATER SHELLS.

QUATERNARY.

No 8. MAMMOTH ELEPHANT'S TOOTH. 9. MASTODON'S TOOTH
10. FLINT IMPLEMENT. 11. STONE GROOVED BY GLACIER

PLATE XXVIII.

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