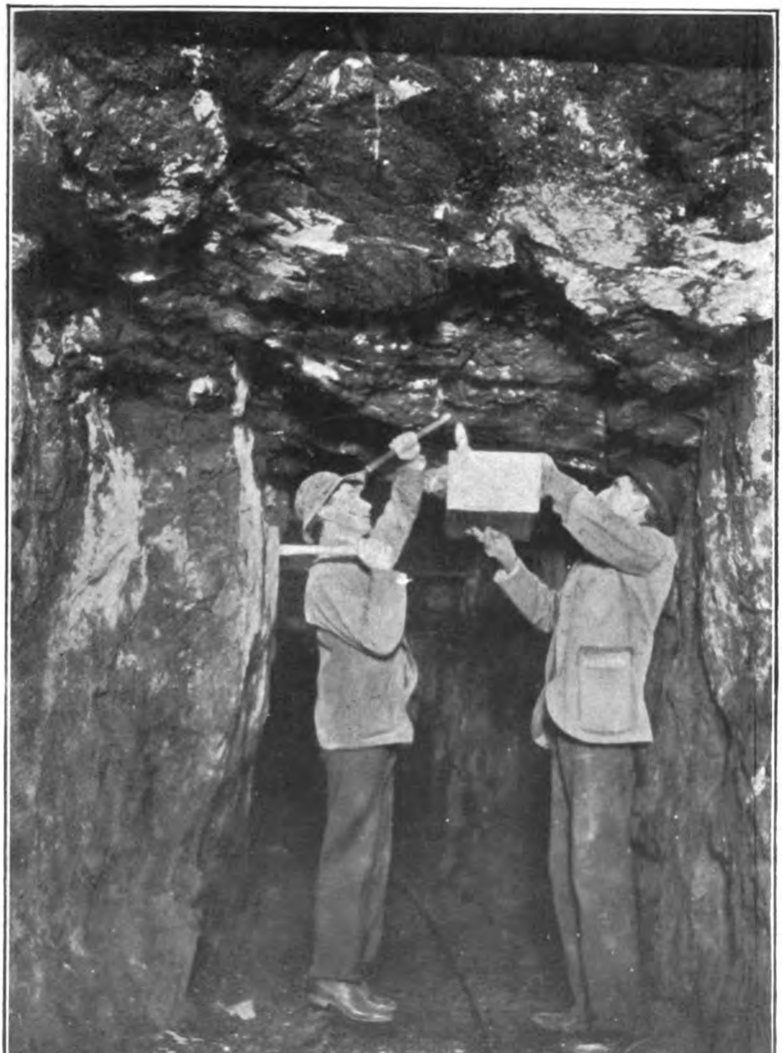

TAKING A SAMPLE.

THE SAMPLING AND ESTIMATION OF ORE IN A MINE

BY

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PREFACE.

The republication of the papers and consequent discussion upon the sampling of ore in mines and the estimation of the tonnage available needs no apology; it is a subject of the utmost practical importance. It is safe to say that the reputation of mining engineers has suffered more from the neglect of this branch of practice than from any other cause. On the other hand, those engineers who have won a deserved reputation for excellence of judgment are the men who, as a rule, have learned early in their career how to take samples which are a trustworthy index to the value of large bodies of ore. Inferences from the results thus obtained are, of course, as important as the sampling itself, but he who is careless in the performance of one duty is hardly likely to be circumspect in the other. There are not many data bearing upon the present and future productiveness of a mine which an engineer can secure at first-hand; all the more reason for the exercise of vigilance in collecting those which are available. Such statements indeed are truisms to the experienced, but they are overlooked with a fatal frequency.

Allied to this subject is the question of the terms to be employed in describing the variously conclusive evidence regarding ore in a mine. The different terms suggested in the course of the discussion, which is herewith reproduced, can be contrasted with the definition brought forward by the council of the Institution of Mining and Metallurgy, London, in a recent circular. It is not likely that the majority of mining engineers will ever agree to confine themselves to the use of exactly the same words, nor would we advocate such a step, because the imposition of cast-iron terms based upon a suppositious uniformity of conditions is calculated to cripple the effort to prepare accurate descriptions of unlike occurrences of ore. No technical word or set phrase will cover the varying degree of evidence obtainable concerning the tonnage of ore in existence in a mine, or in the various portions of it. Nevertheless, while it is unlikely that every one will agree to use exactly the same terms, it is becoming evident, as the light of intelligence is thrown upon the phrase, "ore in sight," that it not only fails to be descriptive, but it is misleading, especially to the average investor in mines who is apt to take it in its literal and most obvious sense. In its ultimate significance only ore in the bins is "in sight"—that is, your ore is *in sight* when you have actually taken it out of the mine. The discussion, however, brings out very clearly the need for precision of language in mine reports, and whether an engineer uses one term or another he should always be at pains to explain just what he does mean. After all, the primary purpose of a report as made by a mining engineer is to state facts as lucidly as possible and in terms which cannot be misunderstood by the person at whose request and expense it has been prepared. It is better to go into details of explanation than to mislead, unconsciously, by the use of terms which are capable of several shades of meaning.

The discussion of these practical matters will, we trust, serve to emphasize the fact that the estimation of the ore-reserves and the exercise of judgment concerning the future prospects of a mine require most of the qualities which make for engineering sense, and that the work of sampling, *plus* the inferences from it, epitomizes those characteristics which, taken together, constitute the difference between a good and a bad mining engineer. If we can assist those who are beginning their professional career, we shall be amply recompensed.

These discussions may point out pitfalls to be avoided by the young engineer. If he profits by the experience of others, he will be exhibiting a noble thrift; if he disregards it, he will be guilty of a prodigal squandering, for there is no improvidence so pitiful as the waste of experience.

T. A. RICKARD,

Editor of *The Engineering and Mining Journal.*

NEW YORK, July 10, 1903.

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By T. A. Rickard.

INTRODUCTORY.

It is held by some that to publish the details of personal practice is unprofessional. Others are of the opinion that while it may be well for professional men to discuss with freedom, but among themselves, the methods they employ in their work, it is poor policy to take the public into their confidence. As regards the first, no defence should be necessary in the face of the recent growth of technical associations which are founded for the avowed purpose of disseminating the knowledge acquired by their members; while, as to the second objection, it suffices to say that the mining engineer suffers from the ignorance of the public no less than the public itself, and, therefore, every step which will promote a better understanding between them is bound to be to the interest of both.

Other considerations, equally strong, prompt the willing distribution of the little knowledge which any individual among us may happen to possess. To give is to receive. No man realizes the limitations of his knowledge until he begins to crystallize it into writing, and if he be moved by a fraternal spirit to give a few hints to those who are his juniors he will find that the effort will teach him more, perhaps, than those he has set out to help. It was well said by a man of wide learning that the best way to find out all about a subject was to write a book upon it.

There was a time when the examination of a mine implied merely a perfunctory visit to the underground workings, the copying of maps and the tabulation of the output.

On this flimsy foundation it was considered proper to base an estimation of values. Other times, other methods. During later years the common sense of every-day business has been introduced into the industry of mining and it has become the practice to investigate with a thoroughness quite unknown twenty years ago. That we owe this betterment to the Rand is likely, for, while those of us who have found an adequate field of activity elsewhere have improved our own methods without conscious suggestions from the outside, it is probable that the very atmosphere of thought breathed by the earnest men of the profession has been influenced by the great developments in the Transvaal and the consequent introduction of a degree of system previously rare in metal mining, so that there has been exerted an influence not less valuable because it may not be directly measurable.

The purpose of examining a mine is, usually, to enable the engineer to pass judgment upon the value of it, both present and prospective. Whatever data he uses as the basis of his opinion must be verified as far as possible. There are many items of information which, on account of the relations of time and place, he may not be able to test at first hand, all the more reason therefore that especial care be taken to get alongside of facts in those matters which are verifiable. Among these the three most important are the determination of the amount of ore in the mine, the average value of it, and the cost of turning it into money.

In practice these three determinations are undertaken in the reverse order, it being obvious that the results of sampling will be meaningless unless you know how valuable the ore must be in order to yield a profit, and it is likewise apparent that no estimate of reserves can be made without the safe basis of one's own sampling of the mine.

"Ore" may be defined as metal-bearing rock which can be exploited at a profit, and it should be unnecessary to distinguish a profit-yielding material as "pay-ore"; however, it is a common habit to include all vein-matter containing any value under the term "ore," it being left to sampling and assaying to differentiate. In the present discussion, whenever the word "ore" is employed, it will mean such material only as at the time of the examination can be profitably exploited; and if there be other lode-stuff which will yield a profit in the event of a further probable reduction of the expenses of mining and milling, then such material will be designated as "low-grade ore"; any other vein-matter, of less value, will be included under the general term "waste."

DETERMINATION OF COSTS.

In arriving at the average costs incurred in the business of a mine, the engineer will encounter conditions which may vary between the extremes of a going concern, having detailed accounts covering a period sufficiently long to afford thoroughly reliable data, and that of an undeveloped mine in an entirely new region where no such data are available.

The first renders it possible to obtain the fullest information, and in such instances, if true figures are not secured, it is often due to mere carelessness. Sometimes the costs are not segregated on the account books, and it will require tactful insistence to get at the actual facts. The investigator may find that there is a tendency to eliminate outlays on improvements for the reason that they are to be regarded as extraordinary items of expenditure, and it is not infrequently found that, in the case of a new equipment, the heavy item of wear and tear is overlooked. Errors may arise from the adoption of figures which cover exceptional periods; for instance, at high altitudes the costs during the summer months are less than in winter on account of cheaper transport, better water supply, and other causes connected with the difference of seasons; similarly, incorrect data as to mining costs may be accepted through overlooking the fact that during the period in question the amount of dead work (exploratory) has been unusually small in comparison to that which is required to keep step with the stoping operations; furthermore, in milling it is not uncommonly found that the power used during a part of the year is derived from water, which is either free of cost or relatively cheap, and that during the remainder of the year coal or wood has to be consumed, to generate steam, at a much greater expense. These are some of the errors against which one has to be on guard. Speaking broadly, the safest way to avoid them is to quote costs covering a long period, long enough to include the vicissitudes of seasons and markets.

Mines are rarely in a stationary state of development; like man himself, they are either growing or declining. When an engineer examines a mine he obtains data which are representative of conditions liable to change on account of the probable expansion or contraction of the entire enterprise; therefore, the figures he gets are apt to represent a passing phase in the development of the particular undertaking, and he cannot arrive at the average costs for the future by simply dividing the expenditure for a given period by the tonnage mined during that period. If the property is a steady-going concern, which has been operated for many years under conditions which are likely to continue unchanged, then indeed he has an easy task, and, given correct figures, he has only to perform a plain sum in simple division. Such cases are rare. Mines are usually bought by capitalists because they think they can enlarge the scheme of operations so as to make the business more profitable than has been the case under the previous ownership. This often entails a sweeping change in the manner of carrying on the enterprise; the entire business is conducted on broader lines, and it is assumed that a larger scale of operation will result finally in a considerable diminution in the average cost per ton. Apart from the fundamental supposition of ore-reserves big enough to warrant the expansion, there arises the question whether the money to be spent in extra equipment, a better trained staff, more vigorous and extensive development of the mine, etc., will result in a reduction in costs to the extent estimated. Experience has shown that sanguine expectations in this regard are not always fulfilled, and that a single mine owner or a small local syndicate can often, in spite of imperfections of administration and equipment, work a mine at a cost per ton which will compare favorably with that of a big company having the large permanent expenditures inseparable from the very nature of its organization. In judging of this, experience is the only guide; no rules can be laid down; each case must be considered apart and on its own merits.

In the case of an undeveloped mine, in a new district, reliable data concerning costs are not available. Under such circumstances it is well to supplement one's judgment by visiting the nearest mines which are being operated under like conditions. To those devoid of experience the situation is honeycombed with pitfalls. West Australia afforded many lamentable examples of this during the years between 1895 and 1898. The majority of reports made at that time omitted to include any estimate of costs, all the available space being taken up by flamboyant statements of results obtained from rough sampling, together with wild prophecies concerning enrichment in depth based upon the presence of sulphides, tellurides, etc. It is a fact that many reports, which confessed to an average of 8 or 10 dwts. of gold per ton of ore, advocated the purchase of mines situated in localities where, at that time, the costs could not possibly be less than 20 dwts. per ton. Again and again one found, in examining a mine which had proved a failure or was about to collapse, that the earlier reports contained the results of assays upon what obviously must have been mere specimens of ore. Such reports had served as the foundation for financiering on a napoleonic scale, and prospects had been highly commended on the basis of an average tenor low even under exceptionally favorable conditions, but quite unattainable in an uninhabited desert several hundred miles from any manufacturing center.

It may seem that the follies of a boom are hardly worth castigation, but they may recur, and if, haply, they do not, then we may at least learn one lesson from them, namely, that it is quite as important to ascertain the average costs as it is to determine the average value of the ore in a mine. To ask a man who has had no experience in the business and management of mines to appraise the value of a prospect situated in a new region is to court disaster. He may be a chemist, geologist, mineralogist, mechanical engineer; however accomplished he may be, unless he has served an apprenticeship as a mining engineer he will be more helpless than helpful. In sizing up the situation it is necessary that a man should know what are likely to be the costs of stoping, timbering, road-making, erection of machinery, equipment, etc., and these things he can only know through actual underground experience and personal participation in the administration of mines. In a new district all the data obtainable will be those furnished by prospectors, diggers and local promoters, very few of whom have accurate knowledge on these points, and when they have it they do not feel called upon to donate it to the novice who happens along. This disregard of the inevitable high costs attendant upon the opening up of a new mining region under unfavorable conditions has been at the bottom of the blunders which have retarded the early development of many districts.

THE DETERMINATION OF THE AVERAGE VALUE OF THE ORE.

The average value of the ore in the *past* can be ascertained from the records of a mine, but to find out the probable average value of the production in the *future* there is no method save that of testing the ore exposed in the workings. This is done by taking representative fragments and then subjecting them to assay. The method is termed "sampling." There are many ways of carrying out the operation; the best are the outcome of experience.

Sampling is expensive. It cost $7,000 to sample one well-known mine, and it cost $12,000 to do the same work in a neighboring property. This did not include the fee of the engineer in either instance. Therefore, an engineer will not commence an elaborate sampling of a large mine unless he has reason to believe that the circumstances warrant it. The cost mounts up into big figures, because of the large number of assistants necessary, the workmen employed in rigging up such timbering as is required to enable the sampling gang to get at the stope faces, the cost of assays, and other expenses. When a mine has very extensive workings the cost is much increased on account of the necessity for putting up special timbering upon which to rig up a temporary platform, or such other arrangement as will permit of convenient access to the faces of ore in the stopes. The figures already quoted indicate very plainly that a thorough sampling must not be lightly undertaken. It should always be preceded by a preliminary investigation. In going through the mine for the first time the engineer will observe that either the present value of it or, perhaps, its future prospects, hinges upon certain facts; it may be a question whether the lower workings exhibit a falling off in value; it may be important to ascertain whether particular ends of levels or particular stopes are really as good as represented. A few samples will throw light on these points, and, if these are satisfactory, then it will be well to test certain portions of the mine more thoroughly, and in this way finally get data which will determine whether a complete sampling of all the workings is justified.

In organizing the sampling gang it is necessary to adopt a system in order to avoid confusion. If it is a small mine, or if the conditions render it advisable to keep quite clear of any assistance from the management, then the engineer will employ only his personal assistants, and, whatever their number, he will divide them into sets, one of whom will break the sample while the other holds the box to receive it as broken. The accompanying photograph illustrates such a couple at work. If, on the other hand, the examination is being made for the owner of the mine, or the conditions otherwise warrant the engineer in accepting the good offices of the management, so that he can utilize the services of workmen on the property, then the task is easier and he can put each of his assistants to work with a miner, the latter doing the muscular work of breaking the ore while the assistant watches to see that the sample is fairly taken, and collects it as it falls into the box or other suitable receptacle made for this purpose.

Next, it is necessary to determine what interval to allow between samples. If the ore is fairly regular in width and value, an interval of 10 ft. will usually suffice; if it is very spotty in value and subject to sudden changes in width, a lesser interval will be required. I have been compelled to sample every 3 ft. in the case of a vein, the ore of which varied between one inch and one foot, with assay-contents ranging between 10 ounces of silver and 1,000 ounces. In such a case extreme care to sample accurately at very short intervals is absolutely imperative in order to get at any kind of idea regarding the average of the ore. When a lode is built up of the common sulphides, such as pyrite or galena, the variations in value are apt to be small, and under such conditions 20 ft. may not be unsafe. Even though you may decide to take samples at much shorter intervals, it is best to start off with a large interval, say of 20 ft., and when the assay-returns are received you can cut this down by taking intermediate samples, if the circumstances warrant it. This will prevent useless labor over stretches of poor ground, and at the same time suggest the proper interval required wherever the workings are in good ore. Having settled this point, the next step is to take the first assistant and measure as regularly as possible along the workings, marking each successive place with colored chalk so that there can be no mistake as to the point where the sample is to be taken. Then, one of the assistants or the engineer himself, at all events a man who has had some training as a mine surveyor, is told off to make sketches of the workings as the sampling proceeds, noting the variations in the vein, the number of each sample and its position, and gathering other information, often extremely important, such as develops in the course of the work done by the sampling gang. Another man sees to the correct labeling of the samples, the sacking and sealing, and the removal of them to a safe place. All the data thus obtained should be set down upon a longitudinal section of the mine, so that they can be generalized by the engineer later on.

THE WORK OF SAMPLING.

The best sampling tool is a moil when struck by a four-pound hammer. Beware of the prospecting pick or the geologist's hammer, or even the larger type of each which the working miner uses; the former insensibly, but inevitably, seeks out the soft places and crevices in the vein, and does not, therefore, yield a true sample, while, as to the hammer, that does the reverse and tends to break off the projecting points, which usually represent the harder portions of the ore. As a rule, the richest parts of the vein are not in the hard quartz, but, particularly near the surface, in the decomposed lode-stuff, so that the pick gives too high an average and the hammer one which is too low. By the right use of the moil and hammer the error of extremes can be avoided. Of course, the excellence of a tool depends upon the right use of it, and it is very easy to get misleading results with the moil as with the other implements already criticized; nevertheless, experience demonstrates that the former is more likely to give an approach to a perfect sample. The ideal method of sampling is the testing of a cheese by a cheese-tester, which removes a core of uniform size. In a mine the intention is to imitate this method as nearly as a material of very variable hardness and texture will allow, an effort being made to cut out a channeling or groove of uniform breadth and depth across the full width of the ore.

Either a moil or a gad is obviously best adapted for this purpose. If the ore is too hard for a moil and a single-hand hammer, get another striker and a double-hand hammer.[1] Do not let the hardness of the ore lead you into the mistake of using dynamite, in the form of "pop shots," in order to loosen the ground. No ground that can be mined in the ordinary way, that is, by drilling holes and charging

[1]A single-hand hammer, that is, one requiring the use of only one hand, ordinarily weighs 4 lbs. A double-hand hammer weighs from 8 to 10 lbs.

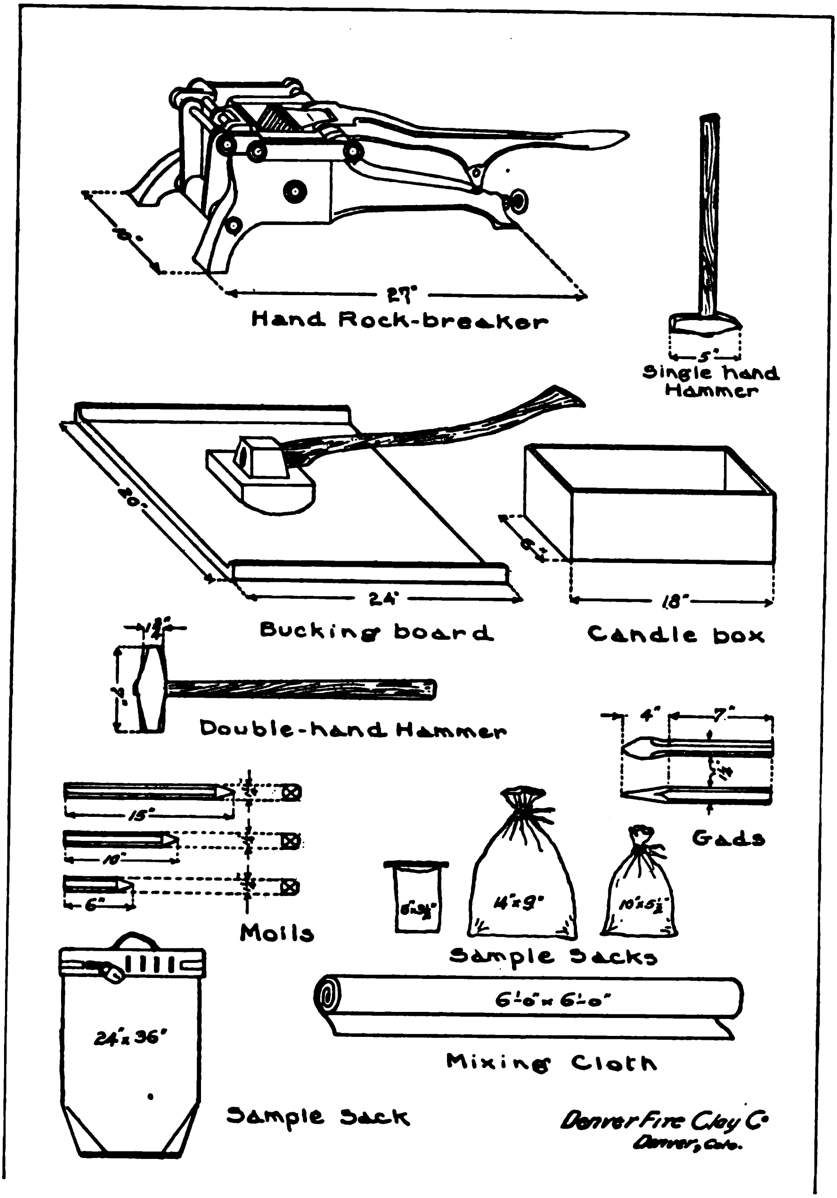

27"
Hand Rock-breaker
5"
Single hand Hammer
20"
24"
Bucking board
6"
18"
Candle box
Double-hand Hammer
4"
7"
Gads
15"
10"
6"
Moils
14"x9"
Sample Sacks
24"x36"
6'-0"x6'-0"
Mixing Cloth
Sample Sack
Denver Fire Clay Co
Denver, Colo.

FIG. I.

them with an explosive, is too tough for a moil struck by a double-hand hammer, when swung by a good man. The use of an explosive introduces an element of danger from "salting," as it is easy to charge the cartridges with powdery gold, which the dynamite will distribute very prettily amid the ore. Of course, one can avoid such tricks by using one's own dynamite, but engineers, as a rule, do not find it convenient to travel about with high-grade explosives. Apart from this, there is a commoner danger. Dynamite tends to break a conical cavity, with the drill-hole as the axis of a cone which tapers inward. The product of the drill-hole would not be a fair sample even if it could all be secured without loss or interference. Usually the explosion of the hole breaks a mass of rock, the cross-section of which tapers from the width of several feet to almost a point, so that as a sample the material obtained is misleading. To pick a sample out of a mass of ore thus broken, or to take it all, is a procedure likely to lead to serious errors.

An accurate sample represents a true cross-section of the ore; it depends, therefore, upon the uniformity of size of the groove or furrow; that is to say, an equal amount of ore must be broken across every part of the entire width of the lode. That is what makes sampling difficult, especially in gold-veins, the predominant matrix of which is quartz, in some form, varied by softer, more friable minerals, which cause marked contrasts in the ease of fracture. In one case, which came under my notice, it took six men (three of whom moiled while the other three held the boxes to receive the samples) the whole of one shift to take three samples across a vein 12 ft. in cross-section, and in accomplishing this they dulled 35 moils. *That* was good, honest sampling.

THE SIZE OF THE SAMPLE.

This question is an important one. It is a matter to be decided by convenience, scientific principle and experience. We will consider the least important first. Large samples are more difficult to handle than small ones and require more assistance. In mountainous regions or in desert places, where facilities for crushing the ore are lacking, it will be found inconvenient to break samples so big that their reduction by hand consumes much time. Occasionally greater inconvenience than this will arise through the want of facilities for removing the ore from the mine without entrusting it to unsafe hands. The factor of time has been mentioned; that of cost must not be forgotten, for time and money are valuable alike to the engineer and to his client, so that the former will find it advisable "to cut the coat according to the cloth." Every engineer runs up against obstacles such as have been referred to, and these vary so much with each individual case that it is needless to attempt to specify them in greater detail.

The size of the sample will also depend upon the facility with which the ore can be broken, because the scientific principle underlying the act of sampling is the obtaining of a true cross-section of the lode. In the case of an ore having the consistency of cheese, which is by no means an impossible occurrence and is approached by certain lodes which are built up of crushed material, a perfect sample can be obtained by running a "scraper" over it so as to make a narrow furrow across the full width of it. This will result in a sample of minimum size. On the other hand, in order to obtain a true sample of a large lode made up of streaks of varying hardness and uneven fracture it will be found necessary to break a hundred pounds at the very least. In such a case it is impracticable to secure a sample of the hardest portions except in large irregular pieces, and this necessitates the breaking of a proportionate amount of material from those places where the ore is much softer or of easier fracture. In hard quartz-veins it will be found that a channeling from 4 to 6 ins. in width and from ½ to 1 in. deep will be adapted to the securing of a true sample; in those instances where the ore has a fairly even grain, as with replacement deposits in igneous rocks of granular texture, it will be found that a groove 3 ins. wide and from ¼ to ¾ in. deep will give a true sample. The minimum size of groove which will yield a correct result should be chosen because any unnecessarily large groove simply increases all the work of subsequent reduction and handling of the samples without a commensurate increase of accuracy in the final results. Furthermore, one has always to remember that two samples of 50 lbs. each at 5 ft. apart are better than one sample of 100 lbs. at an interval of 10 ft. The whole idea underlying the operation is that of securing an average, and it is obvious that the larger the number of data the more likely one is to approximate the truth.

The next factor is more important than the two already considered. I refer to that invaluable guide, Experience, without whom all work of this kind is as dangerous as is mountaineering in the Alps to a thoughtless tenderfoot. To one who has done his own sampling and assaying there has often arisen the inevitable contrast between the dimensions of the sample and those of the gold button which represents its contents. Whatever the size of the original sample, the outcome is merely one button of minute size. Gold, as at present known to exist in workable lodes, occurs in a metallic form and is usually disseminated through the ore in an extremely irregular and sporadic manner. As a consequence, the final pulp taken for assay, and weighing, as a rule, about an ounce, if not less, is apt to contain a coarse speck of gold, the accidental presence of which vitiates the result. Whatever the weight of the original sample, whether 5 lbs. or 500 lbs., the particular particle of gold included within the final pulp will have the same effect of exaggeration, save in one respect, viz., that, given the fact of its occurrence in the original sample, it is more likely to find its way into the assay pulp of a small sample, the latter being to the former in the proportion of 1 oz. to 5 lbs., or, say, 1 to 80, than in a large sample the final pulp of which represents, say, one part in 8,000 parts of the original. When, however, the gold is not present in the usual condition, but occurs in that pulverulent state known as "mustard gold," characteristic of the metal when it is the product of decomposed tellurides, then the more even dissemination of the gold causes it to be spread throughout the sample so as to make the size of the latter a factor of safety. Of course, usually, the particles of gold become flattened out during the process of crushing (on the buck-board) previous to the assay, so as to appear on the screen in the form of scales, termed "metallics," and the practice is to pick them up, weigh them, cupel them, and then determine their weight in relation to the weight of the sample; but this does not overcome the interference with accuracy because, although this determines the proportions in which such particles occurred in the particular sample, it does not give any clue as to the relative importance of such particles in the enrichment of the entire lode. Naturally, in small samples the interference is relatively greater and therefore more clearly recognizable. On the whole, therefore, one comes back to the conclusion that the best rule to follow is the taking of the smallest sample consistent with securing a true average of the lode at each cross-section. The larger the sample, the more difficulty in handling it, the more persons required to help and the greater the chances of poor work. Let me mention an example. Two engineers examine a mine, and, in carrying out their investigations, one gets large samples, resulting from a wide groove, while the other takes small samples, the product of a smaller groove. Although both samples are equally good, in so far as they represent an approach to the true cross-section of the lode at each place sampled, nevertheless the former, on account of the greater size of the samples, is, theoretically, the better of the two. However, the second engineer employed fewer assistants, and all those whom he employed in this capacity were men whose antecedents he knew and whose reliability he had previously tested, while the first engineer engaged his gang of samplers at the mine, most of them being vouched for by the management or by a fellow-engineer; yet the chances of error were increased by the number of men employed, the real ability of each to take true samples being merely assumed on the statement of some one else.

When the samples are broken they are put into sacks which are not marked upon the outside, but are, preferably, labeled by inserting a tag with the number upon it. This tag is often merely a piece of paper, detached from a notebook, but in this form it is apt to get torn or the number upon it obscured, especially when the ore is moist, therefore it is best to use a metal or wooden tag especially prepared for this purpose. The latter will be found convenient. Get a lot of small pieces of soft wood (1/8 in. thick, 1 in. wide and 1½ ins. long), and mark the numbers of the samples upon them by the use of a hard pencil; this will remain as a visible indentation even after the pencil trace has been rubbed off.

The samples are then removed to a safe place, either temporarily in the mine itself or to a building where they can be locked up. Then comes the work of reducing them in bulk by crushing and subdivision. If an assay office is conveniently at the engineer's disposal, he will probably find a rock-breaker which he can use, otherwise a portable rock-breaker, worked by hand, will be found a useful machine to take with him when a large sampling job is to be done. In the absence of these conveniences the ore is broken by hand with a cobbing hammer, to the size of walnuts, and then subdivided. This is followed by further reduction in size and subsequent subdivision by quartering.

It is usual to place the crushed ore upon a square sheet of canvas, which is rolled backward and forward in opposite directions in such a manner as to mix the ore lying upon it, until finally a conical pile is left standing in the center. This is flattened to a frustum previous to quartering, the two opposite quarters being taken and again mixed previous to a further mixing and quartering, until the bulk of the sample has been reduced to the size considered suitable for shipment to the assay office.

The foregoing method is open to criticism. In the first place, the rolling canvas is not nearly so good a way of mixing as it looks, the fines are apt to slide over the surface of the canvas instead of becoming thoroughly mingled with the coarser particles; moreover, the cone which is finally formed is deceptive in that the fines are likely to be collected not at the center of the base of the cone, as is supposed, but to one side, so that, in quartering, any particular division may include an undue proportion of the fines, which usually form the richest part of the sample. Further, in flattening the cone into a frustum, for convenience in quartering, it is difficult to distribute the ore evenly, and though great care be taken to draw the ore in a straight line outward, toward the circumference, the distribution is liable to be faulty, and this part of the work may be so imperfectly done as to become a source of error.

An alternative, and better, method can be suggested. Get a few short boards, or cause some to be sawed to the required length, of about 6 ft., and put them together so that they will make a platform which can be kept firmly in place by being spread upon a couple of sills and wedged in with stones. Then, if the joints are not tight, put your sheet of canvas upon it, not to roll the samples within it, but merely to prevent any leakage of fines through the cracks between the boards. When the sample is crushed, gather it up with a scoop or other handy implement to the center, lifting the broken ore, shovelful by shovelful, and pouring it as nearly as possible at the same central point so as to aid the mixing of it. In doing this it will be found convenient to use the "cone," in vogue at many smelters, which consists of a sharp central cone, made of iron, with four thin radiating partitions which cause the ore, as it falls upon the center, to become quartered.

In order to do accurate work at this stage, it is necessary that the particles of ore should not vary too much in size. The fines are apt to obscure the fact that there are a good many large lumps, and the unaided eye is likely to mislead in this respect. For this reason it is well, if convenient, to use a wire screen, say, ½ or ¾-inch mesh, or perhaps two, one of ¾ and the other of ¼-inch mesh, to be employed at successive stages of the operation, so that the maximum size of the particles can be kept within defined limits. It is an easy matter to take a piece of wire cloth, say 1 foot square, and have a frame put around it when you reach the mine.

If it is necessary to send the samples to a distant assay office or to take them with you on your departure from the mine, then it becomes convenient to reduce them until they weigh only three or four ounces each. In doing this the engineer will anticipate the work of further reduction, which is usually carried out by the assayer. The samples will be crushed smaller and passed through, say, a 10-mesh screen, and, instead of quartering, it will be well at this stage to use a gridiron sampling device, which consists of a series of metallic scoops separated by vacant spaces of equal width, so that one-half of the ore falls through while the remainder is arrested. When this method has reduced the bulk of the samples to the desired dimensions, they are put into small paper or canvas sacks, the latter preferably, especially if it is intended to ship them a long distance.

If genius be, as has been authoritatively stated, "an infinite capacity for taking pains," then it is safe to say that genius is exactly the mental quality needed for the humdrum work of sampling, for to do it conscientiously and well requires patience, strength and an amount of unwearied watchfulness sufficient to elevate this common task to the level of a fine achievement. It requires an obstinate persistence to get a true average across a hard and tough quartz-vein; any relaxation of care or muscle will at once result in the spoiling of the sample and the consequent introduction of an error into the calculations of the engineer. It needs judgment to know how to treat a cavity (or vug) or an unusual inclusion of waste rock; it needs a nice sense of proportion to avoid cross-sections which are exceptional, to break an equal weight of ore along a line 10 or 12 feet in length, and to get the true width of an irregular cutting. For these reasons it is best, when carrying out an arduous scheme of sampling, to divide the muscular from the mental work, allowing a miner to do the actual breaking under the direction of an intelligent trained assistant, who holds the receptacle for the ore as it falls, and at the same time watches the movements of the miner. Further, it is well to make the hours of labor short, so as to avoid an excessive strain on the faculties, such as will cause relaxation of the intent watchfulness and care necessary to good sampling. In order to escape the risk of inferior work, it is good practice to vary it, as, for instance, by putting the assistants to surveying or mapping for a day or so, at intervals. Otherwise your men are apt to get "stale" through weariness. How tiresome such work is those can testify who have done much of it; the dirt, the wet, the strained positions, the splinters that hit the face and hands, the obstinacy of rock and circumstance, the weary iteration of it—these require something better than mere mule-like persistence to overcome them, and the man who can do a difficult piece of sampling honestly and well can be entrusted to do work for which much greater credit is usually given by those in authority.

PRECAUTIONS IN SAMPLING.

Although the greater thoroughness with which mines are investigated nowadays has made trickery scarce, instances of the latter do occur occasionally. They are rarely exposed because of the lack of evidence, and therefore the occurrence of them is obscured amid those failures and disappointments in mining which arise from other causes. The tampering with samples, called 'salting,' and the blocking up of workings which might give unfavorable testimony regarding the condition of a mine are two possibilities against which one must be continually on guard. To prevent 'salting' it is imperative that the work be done by trustworthy assistants; and in the case of a large mine, where it becomes necessary to employ workmen whose antecedents are unknown, it is well to arrange that the work be done in pairs, the miner breaking the samples under the direction of an assistant, who holds the box to catch the sample as it is broken. When the sampling is done it is well for the chief himself to take a certain number of samples, aided by his first assistant, these samples being taken, not at haphazard, but in such a way as to check the previous work. One of the best guards against any successful tampering with one's samples is to take an occasional sample of waste. If the samples are all salted, the assay of the waste will disclose the fact. Occasionally it may be well to fill one or two sacks with material the exact assay contents of which have been previously determined. In any event, it is better not to use sacks which are numbered or otherwise marked on the outside, because, should trickery be purposed, such marks make it easy to note from what parts of the mine the various samples come and to 'salt' them accordingly. It is well to assay the samples on the spot, if a suitable assay office is available, particularly when the engineer, or one of his assistants, is a good assayer, as is frequently the case. Of course, in using a strange assay plant it is necessary to guard against fraud, and to this end it is well to test the fluxes used by assaying a charge without ore every time a batch of samples is put through the furnace.

During the interval which elapses between the time when the sample is first broken in the mine and its final assay, it is necessary that the sack containing it should be sealed. It is a good thing to use uncommon wax and an uncommon seal, so as to render trickery more difficult. It is well even to use a peculiar kind of string for tying up the sacks. "He is most free from danger who, even when safe, is on his guard." Any extra precaution should never be considered a nuisance; on the contrary, it ought to become a habit. Cases of 'salting' have been known where the ore has been artificially enriched without breaking the seal and without puncturing the sack, and I know of an instance in which samples of copper ore, put into a carpet bag, were withdrawn and substituted with others by removing the bottom of the bag and sewing it up again while the engineer was asleep. "Dead things will crawl." "Eternal vigilance is the price of safety."

Unfortunate consequences have sometimes ensued from the failure of an engineer to see *all* the workings of a mine. This may be due either to carelessness or oversight, but it may also be due to the rascality of the mine owner. Cross-cuts are sometimes blocked up with old timbers, drifts may be allowed to cave, shafts may be under water; in each of these cases the engineer must realize that he is under a responsibility if he passes judgment on the mine without seeing for himself what these inaccessible workings have to tell. Their testimony may be unfavorable; it usually is in such cases; but, on the other hand, there may be circumstances which influence the owners in desiring to temporarily depreciate their property.

An opportunity for splendid business was lost in the case of the great Broken Hill mine through an error of this kind. An engineer, and a good one, too, was engaged by a Melbourne financier to make an examination of the new discovery at Broken Hill, with a view to the purchase of an interest. He duly reached the mine, and found a gang of miners engaged in sinking a prospect shaft, which at that time, in 1885, was about 70 feet deep. Much to his annoyance, he was refused permission to go underground, except by written order from the manager, who had left the day previous for Adelaide. Disappointed, but not without hope of getting information, he chatted with the men, more especially the foreman, and endeavored to pump the real facts out of them. Their talk indicated that no rich ore had been found, and that the prospects were poor. He examined the dump, took samples of it, and finally returned to Melbourne via Adelaide. The samples from the dump gave 16 ounces of silver at the best. He advised his client to keep out. A few days afterwards it became known that a rich mine had been found at Broken Hill. He had been fooled, the discovery having been made just previous to his visit and covered up for a particular purpose. That mine has since produced over 100,000,000 ounces of silver.

This is one side of the question. It is rarely that a bonanza is kept out of sight. As a rule, the exclusion of an engineer from certain parts of a mine is intended to cover unfavorable testimony. It is therefore of the greatest importance, more especially in a small mine, the character of which has not been truly established, that an effort be made to personally investigate all the workings. Intentional deception is, I am glad to believe, rare; nevertheless, in passing upon the purchase of property, the engineer should write across his notebook, "*Caveat emptor.*" One instance will suffice. Let the accompanying section, Fig. 2, represent the workings of a small mine, where the level A D is 200 ft. from surface and F M is 100 ft. deeper. Above A D there has been a line of stopes from B to C, a distance of 200 ft., all the ground being worked out, with results testified to by certified returns from mine and smelter. When the mine is sampled, it is found that there is good ore in the floor of level A D, and along the back of the lower one F M, as indicated in the section. Moreover, the raise at H is going up in good ore, and the drift (at M) is proceeding in ore of an average tenor; in short, the evidence proves that the ore-body is persisting downward with a pitch to the east, similar to its behavior in the upper workings. No winze has been sunk below A D. At E there is a hole about 5 ft. deep, which, according to the statement of the superintendent, is being used as a sump to catch the drippings from the stopes and thus prevent the water running down the shaft. A small pump at A sends this water to surface.

All looks serene and straightforward, but the facts are as shown in Fig. 3. At E there is a vertical winze which is deeper than 5 ft., and has been carefully filled up. From the bottom of this (at P) an incline has been run down to N; at N there is a drive R O, and all the ground above has been stoped out bodily, leaving a mere shell under the level between B and C. The raise H is situated so as

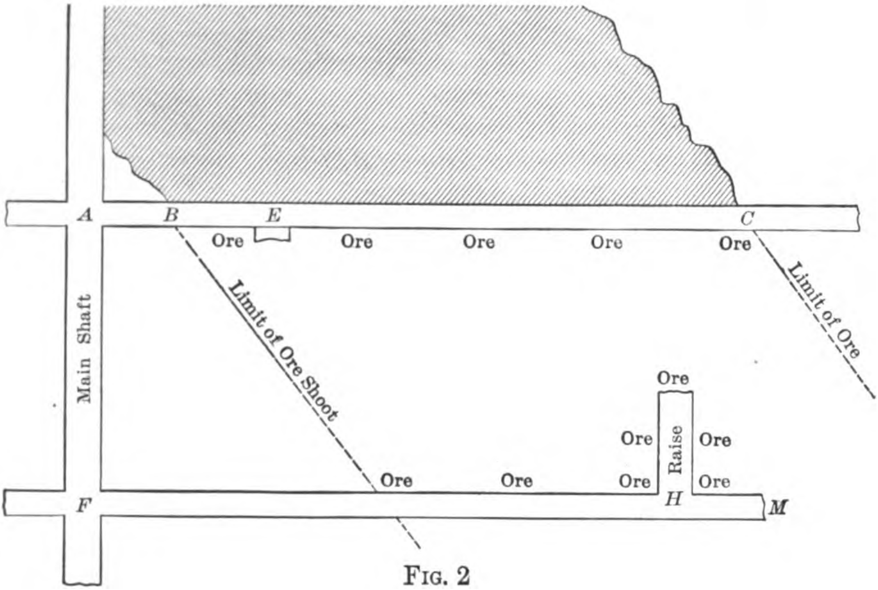


FIG. 2

Stoped

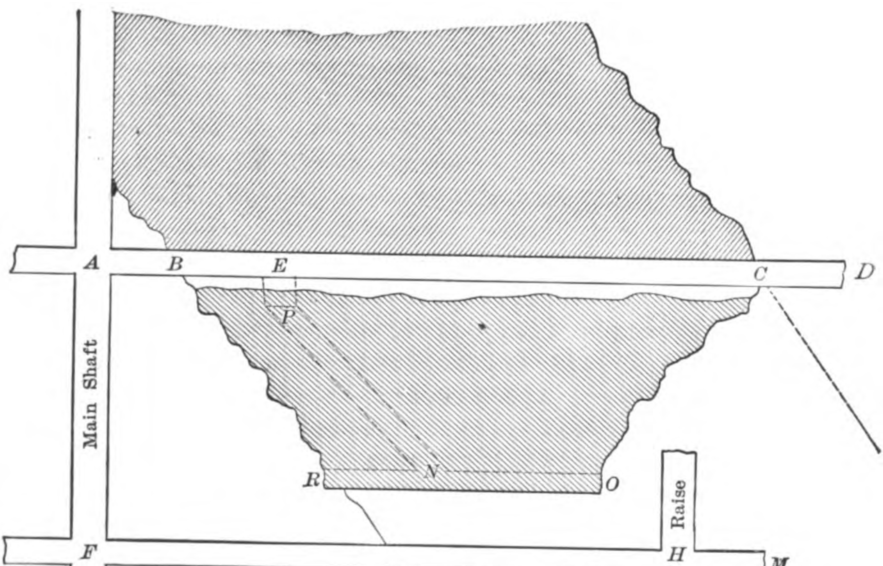


FIG. 3

Hidden Stopes **Known Stopes**

to miss these secret workings. The heart of the ore-body has been taken out, and a clever piece of trickery has been attempted.

As a possible check against the perpetration of such practical jokes, it is not out of place to ask the manager in charge of the mine to sign a statement which sets forth that he has informed the engineer of all the existing workings, and to this can be attached a map or a brief description of such workings as are inaccessible through caving or other causes. Such a paper will serve as a record to make clear the position of the engineer and fix the responsibility on the management of the mine should false statements have been made with the intent to deceive.

WRONG METHODS OF SAMPLING.

In the early days of Western Australia, and, indeed, one may say in the early days of most gold-fields almost anywhere, it was a common practice for the gentlemen, vaguely known to the press as "experts," to sample an incline shaft, on a vein, by having a few shots put into the ore, and then collecting the material thus thrown down to the bottom of the shaft and having it hoisted to surface, where it formed one of those "large" samples, the tonnage of which was referred to with pride in the reports as evincing an accurate testing of the value of the ore in the mine. Such work is the travesty of sampling. A bunch of specimen ore, a few inches in extent, was enough to vitiate the whole result. Such spots of free gold were commonly characteristic of the Westralian reefs near the surface, and, if this unintentional "salting" was not enough, the subsequent performance at surface and the handling of the ore by a large number of men of unknown character gave sufficient opportunity for further tampering with this suppositious sample. There is a lot of this sort of thing perpetrated during the windy days of mining booms, not in Western Australia alone.

In the case of wide lodes—that is, such as exceed the average stoping width—it is advisable to take sectional samples, dividing the lode into successive divisions, each of which is, say, 4 ft. across. The results thus obtained will be useful in indicating the distribution of values. Occasionally it will be discovered that a vein is being worked for a bigger width than circumstances justify, while, quite as commonly, it may be found advisable to change the practice radically, and in the opposite way; that is, it may be proved by sectional sampling that, while a mine cannot be profitably operated if only a narrow width of rich ore is mined, it will become remunerative if it is worked on a larger scale by adopting a bigger stoping width, so as to include parallel streaks, feeders and branch veins, which will yield a much bigger tonnage of low-grade ore, unsuit-

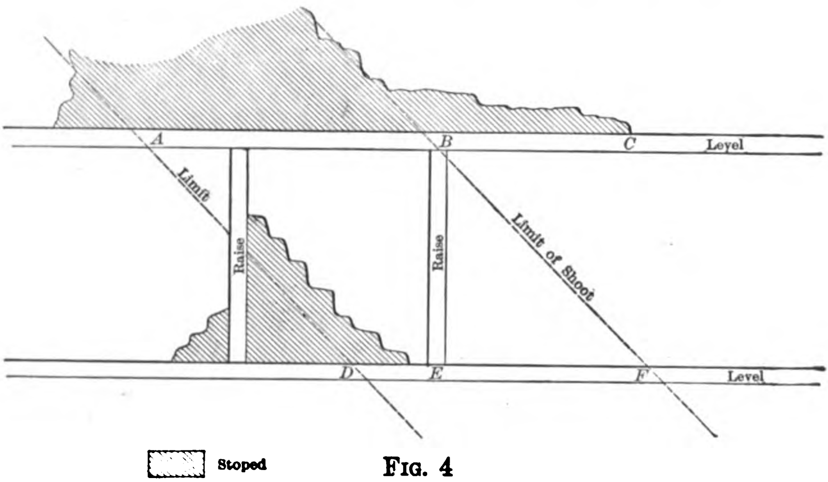


Fig. 4

able, it may be, for shipment, but profitable in a mill, to be erected at the mine or near it.

In the sectional sampling of wide lodes particular care must be taken to get the true width. Measurements must be taken at right angles to the walls of the vein. In sampling, however, a horizontal line may be followed, if it is convenient; it will give a larger quantity of ore than a right-angle section, but if each sample is taken along a parallel line, the proportion will be maintained and a true sample will be secured.

The importance of an accurate recognition of the slope of a vein and the pitch of an ore-shoot, when making estimates, cannot be emphasized too much. An example will be of service. Thus, in Fig. 4, A B and D F represent an ore-shoot traversed by the two levels, which are 100 ft. apart. The ore has been stoped out above the upper level, and a portion had been removed between the levels. The stopes—inaccessible—above B C and the stoping begun at the bottom of the left-hand raise are calculated to obscure the real condition of affairs. The engineer samples the raise E B and the back of the level between E and F, with results which cause him to assume a block of ore A E F C. He has failed to recognize the pitch of the ore-shoot because the stoping above B C has obscured it. It will be said that if he had sampled the bottom of the level this mistake might not have occurred, but the sampling of bottoms is not always practicable, and is usually very unsatisfactory on account of water and other factors. It is not realized often enough that ground which has been stoped was not necessarily profitable. Stopes are frequently started with the hope of an improvement or with the purpose of testing a run of ground. For this reason the workings of a mine, both underground and on the map, are apt to suggest unwarranted deductions as to the distribution of ore, and many misleading inferences have been caused thereby. Thorough sampling will usually make the truth clear to an experienced man.

Among the things to be avoided one must mention the so-called "grab" sample. This is the last resort of incapacity. A grab or haphazard handful of ore is taken indiscriminately from all over a pile of ore at the face of a level or in the stopes, and this is put into a small sack for subsequent assay. The idea of the grab sample is to shut your eyes and be "absolutely impartial," but the brutal fact is that one usually gets a deceptive proportion of the fines and quite disregards the large pieces of waste or poor rock scattered through the heap. It is still the practice in many mines for the foreman to take samples in this manner while making his daily round of the workings. As a consequence, the record of the assay office is often an iridescent dream, which may mislead the management and become the cause of a serious error in the estimates of ore. It takes more time to use a moil and a hammer, thereby obtaining a true average sample, than it does to pick up a "grab" and stick it into one's pocket or into a sack; for this reason the former procedure is objected to by many foremen. The fact is, the daily sampling of the faces of ore should be a task allotted to men who have the time and the training for such work; it should be no part of the duty of a foreman or a shift-boss, both of whom are usually men of a type which confounds system with "red tape," but it should be placed in the surveyor's department, so that the record of results can be incorporated with the maps of the mine. *"Chacun à son métier et les vaches seront bien gardées."* It is a good saying. Let the important work of sampling be put into proper hands, separate from the particular supervision of the operations of the mine, the control of the men and other departments with which it has no kind of connection. The ordinary multifarious official has no time for a job which essentially requires time to do it properly. And before everything else, begin by prohibiting "grab samples" in any form!

CALCULATIONS AFTER SAMPLING.

The calculations consequent upon sampling are based on the theory of averages. An arithmetical mean is the sum of all the numbers forming the series of figures under consideration divided by their number without reference to their weight or relative importance among themselves. This method has been applied to the results of sampling, with most unhappy consequences. Thus, let the following series of figures represent the data obtained from sampling a length of 100 ft. of gold-bearing ore at intervals of 10 ft.:

Width.	Assay.
4.4 feet	2.35 oz. per ton
6.2 "	.45 oz. " "
7.6 "	.62 oz. " "
4.0 "	.85 oz. " "
2.5 "	1.02 oz. " "
3.6 "	2.40 oz. " "
2.5 "	4.25 oz.
.8 "	5.20 oz. " "
1.2 "	4.65 oz. " "
2.2 "	3.21 oz. " "
35.0	25.00

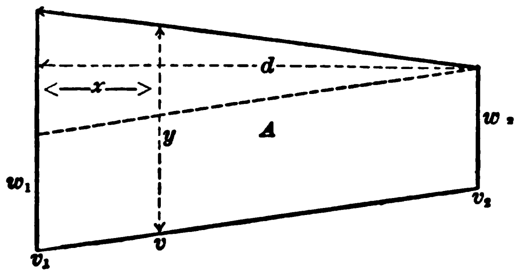
The arithmetic mean yields 3½ ft. of ore averaging 2½ oz. of gold per ton. This is woefully wrong. It disregards the fact, for instance, that the third sample yielded 7½ ft. of ore containing only 0.6 oz. of gold, while the richest ore, at the eighth sample, was less than 1 ft. wide.

The geometrical mean is the sum of such figures divided by their number, with due allowance made for their weight. This is done in practice by what many call the "foot-ounce" method, which, applied to the foregoing example, works out thus:

Width.	Assay.	Foot-ounces.
4.4 feet	2.35 oz. per ton	10.34
6.2 "	.45 oz. " "	2.79
7.6 "	.62 oz. " "	4.71
4.0 "	.85 oz. " "	3.40
2.5 "	1.02 oz. " "	2.55
3.6 "	2.40 oz. " "	8.64
2.5 "	4.25 oz. " "	10.62
.8 "	5.20 oz. " "	4.16
1.2 "	4.65 oz. " "	5.58
2.2 "	3.21 oz. " "	7.06
35.0	25.00	59.85

The assay per foot of width is 1.71 oz. per ton, instead of 2½ oz. In matters of this kind mathematical reasoning confirms the conclusions of rough common sense. The method just described is based upon the higher mathematics, as the following integrations, kindly suggested by Mr. Ross Hoffman, will demonstrate:

Problem 1.—To determine the average value of the section of vein A between the samples whose widths are w_1 and w_2, and values v_1 and v_2, respectively, under the assumption that the values vary gradually over the area from v_1 to v_2 in the direction d, then at any distance x from w_1 the value



$$v = \frac{x}{d}(v_2 - v_1) + v_1 \quad (1)$$

also

$$\frac{d}{w_1 - w_2} = \frac{d - x}{y - w_2} \quad \text{or } y = \frac{x(w_2 - w_1)}{d} + w_1 \quad (2)$$

$$A = \frac{(w_1 + w_2)\ d}{2} \quad (3)$$

$$\int_{x=o}^{x=d} v\, y\, dx + A = \text{average value for the section A.}$$

From 1 and 2 $v\,y = \frac{x^2}{d^2}(w_1 v_1 + w_2 v_2) +$

$$\left(\frac{x}{d} - \frac{x^2}{d^2}\right)(w_2 v_1 + w_1 v_2) + \left(1 - \frac{2x}{d}\right) w_1 v_1$$

$$\therefore \frac{2}{(w_1 + w_2)\, d} \int_0^d v\, y\, dx = \tfrac{2}{3}\, \frac{w_1 v_1 + w_2 v_2}{w_1 + w_2} +$$

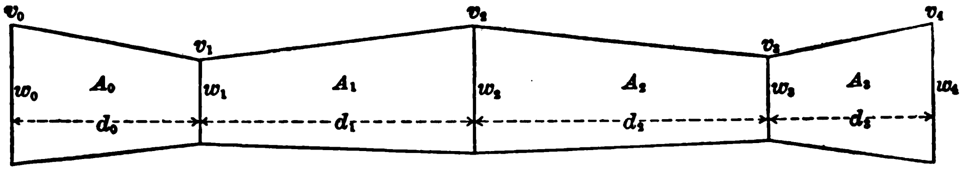
$$\tfrac{1}{3}\, \frac{w_2 v_1 + w_1 v_2}{w_1 + w_2} = \frac{w_1 v_1 + w_2 v_2}{w_1 + w_2} + \tfrac{1}{3}\, \frac{(w_1 - w_2)\ (v_2 - v_1)}{w_1 + w_2}$$

The last term = O when $w_1 = w_2$ or $v_1 = v_2$

Under normal conditions, where ordinary sampling can be depended on to give fairly approximate averages, this last term will be small enough to neglect. (See by substitutions.) Hence

$\frac{w_1 v_1 + w_2 v_2}{w_1 + w_2}$ can be taken as the average value for section A.

Problem 2.—To find the average value from a number of samples taken as above, where w equals width of



sample, v equals value, d equals distance between samples and A the area of various sections of vein between samples:

$$A_0 = (w_0 + w_1)\frac{d_0}{2} \quad \text{average value for } A_0 = \frac{w_0 v_0 + w_1 v_1}{w_0 + w_1}$$

$$A_1 = (w_1 + w_2)\frac{d_1}{2} \quad \text{"} \quad \text{"} \quad \text{"} \; A_1 = \frac{w_1 v_1 + w_2 v_2}{w_1 + w_2}$$

$$A_2 = (w_2 + w_3)\frac{d_2}{2} \quad \text{"} \quad \text{"} \quad \text{"} \; A_2 = \frac{w_2 v_2 + w_3 v_3}{w_2 + w_3}$$

$$A_3 = (w_3 + w_4)\frac{d_3}{2} \quad \text{"} \quad \text{"} \quad \text{"} \; A_3 = \frac{w_3 v_3 + w_4 v_4}{w_3 + w_4}$$

(See Prob. 1.)

$$\frac{\Sigma\ (A \times \text{average value for } A)}{\Sigma\ A} = \text{average value over the}$$

$$\text{whole area sampled} = \frac{(w_0 v_0 + w_1 v_1)\frac{d_0}{2} + (w_1 v_1 + w_2 v_2)\frac{d_1}{2} + (w_2 v_2 + w_3 v_3)\frac{d_2}{2} + (w_3 v_3 + w_4 v_4)\frac{d_3}{2}}{\frac{w_0 (d_0)}{2} + \frac{w_1 (d_0 + d_1)}{2} + \frac{w_2 (d_1 + d_2)}{2} + \frac{w_3 (d_2 + d_3)}{2} + \frac{w_4 (d_3)}{2}}$$

$$= \frac{v_0 \left\{\frac{w_0 (d_0)}{2}\right\} + v_1 \left\{\frac{w_1 (d_0 + d_1)}{2}\right\} + v_2 \left\{\frac{w_2 (d_1 + d_2)}{2}\right\} + v_3 \left\{\frac{w_3 (d_2 + d_3)}{2}\right\} + v_4 \left\{\frac{w_4 (d_3)}{2}\right\}}{\left\{\frac{w_0 (d_0)}{2}\right\} + \left\{\frac{w_1 (d_0 + d_1)}{2}\right\} + \left\{\frac{w_2 (d_1 + d_2)}{2}\right\} + \left\{\frac{w_3 (d_2 + d_3)}{2}\right\} + \left\{\frac{w_4 (d_3)}{2}\right\}}$$

The bracketed terms represent areas and may be considered the importance or weight factors with which the various sample values taken separately enter into the general average value for the whole area. It is equivalent to giving each sample value an importance (or weight) proportional to its sample width multiplied by half the sum of the distances to the two adjacent samples.

Averaging in this manner assumes, as in problem 1, that the values between various adjacent samples change gradually.

If the samples are taken equidistantly, the above average becomes

$$\frac{v_0\left(\frac{w_0}{2}\right) + v_1 w_1 + v_2 w_2 + v_3 w_3 + v_4\left(\frac{w_4}{2}\right)}{\frac{w_0}{2} + w_1 + w_2 + w_3 \frac{w_4}{2}}$$

which, with the exception of the two end samples, is simply giving each value an importance in the general average proportional to the width of its sample. The two end-sample values are shown to have half this importance, though in practice, with many samples under consideration, it is customary to give the two end samples the full importance proportional to their respective widths.

In the calculations for tonnage the cubic feet of ore are converted into tons on the basis of a certain specific gravity; thus, quartz is usually taken at 15 cub. ft. per ton, while ores containing sulphides are rated at 8 to 12 cub. ft. It is not unusual to guess at this proportion, because experience does enable an engineer to approximate the correct figure fairly well. But it is a dangerous practice. Approximations should never suffice where greater accuracy is possible. It is well to weigh a series of measured pieces of ore or to determine actually the specific gravity of a few pieces of average vein-stuff. Surface quartz, on account of its cellular structure, may require 20 cub. ft. to weigh a ton. Pyritic ores will vary to an extent hardly appreciable even to the experienced eye. Grievous errors in tonnage estimates have been caused by the assumption of an incorrect basis of calculation.

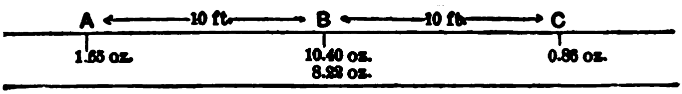
A minor source of error is sometimes created by the occurrence in the vein of numerous cavities, or 'vugs,' as the miners call them. In some cases they form a very appreciable proportion of the space occupied by the lode, so that they are apt to lessen the tonnage obtainable from a block of stoping ground.

THE QUESTION OF "HIGH ASSAYS."

In these calculations, whether they be mathematical or rough-and-ready, it is assumed that where two adjoining samples vary there is a gradation from one to the other. Generally the assumption is warrantable, but occasionally the difference between any two such adjoining samples is so marked as to require further consideration. In the sampling of gold mines, especially where the metal occurs in a native condition and visible to the eye, there will be a few very high results which affect the average of a run of samples to an extent quite out of proportion to the importance of a single sample.

This question of "high assays" demands careful discussion. It can be viewed from two standpoints: the seller of a mine is apt to argue that if you are going to base an estimate of the ore-reserves upon the results of sampling and assay you ought to take all the data without favor, just as they come, and that to eliminate high assays is no more fair than it would be to omit poor ones; to this the engineer, representing the interests of a possible purchaser, will reply that the occasional very high assays are largely accidental, that they affect the estimates to a degree out of proportion to their weight, and to an extent by no means comparable to the omission of an equal number of poor results; finally, he will murmur under his breath something about a factor of safety being necessary.

In the first place, it is incumbent upon the engineer to find out whether these occasional high results do, or do not, represent the average of the ore, not at the particular place sampled only, but over the whole space or interval which that sample is supposed to represent. Each sample in the final calculation speaks not for a spot, but for a section of the vein, the length of which is the interval between samples and the height is the distance separating it from the next working overhead or underfoot; thus, when the distance between samples is 10 ft. and the next series of samples is on a level 100 ft. distant, above or below, then the section represented by a single sample contains 10 by 100 ft., or 1,000 sq ft., which, if the vein be, for example, 3 ft. wide, may contain over 200 tons of ore. In practice the responsibility of one series of such samples is shared by that of a corresponding series taken on the level above or below; nevertheless, it is obvious that a single sample represents something very different to the mere spot or place in a particular working. In order to answer the question whether an individual high assay is accidental or representative, the only thing to do is to re-sample at the same place; if the result is confirmatory, then evidently that spot is as rich as the first sampling indicated. But this does not determine whether the high values gradate on either side toward the adjoining samples. Thus, if A, B and C in the diagram represent three points, 10 ft. apart, which have been sampled with the results shown, then, if B assayed 10.40 oz. and was re-sampled with 8.22 oz. as the assay return, the next question arising is



whether the ore midway between B and A, or B and C, is correspondingly intermediate in value; for this is what the calculations assume. For this reason it is best to check the high assays by taking further samples at these intermediate places, thereby finally settling the query whether the high results are trustworthy factors in estimating the average value of the ore-bodies.

The treatment of "high assays" has caused much discussion among engineers, especially when they are encountered in the course of a sampling, the results of which are to decide the price of a mine. The seller, or his representative, is apt to suggest that a re-sample of poor spots is also in keeping with the theory of the whole business, and to this I would say that where a barren or nearly barren result is obtained amid a series of samples indicating good ore it *is* correct to re-sample such a place or places. The occasional barren and the occasional high assay return, however, are not comparable in their effect upon the estimates. In the first place, the "nil" or "trace" indicates the entire absence of the metal and has not the accidental feature arising from the presence of a stray speck of gold, which may cause the abnormally high assay; further, one very high assay affects the calculations more than a number of poor ones, supposing both to be deviations from fact, as can be easily shown, thus: Take the following series of samples and assay returns:

Width.	Assay.	Foot-ounces.
7 feet	1.22 oz. gold	8.54
4 "	.54 oz. "	2.16
12 "	1.20 oz. "	14.40
8 "	2.20 oz. "	17.60
5.3 "	27.40 oz. "	144.22
7 "	1.60 oz. "	11.20
3.5 "	.95 oz. "	3.32
6 "	.39 oz. "	2.34
6 "	trace "	...
7.2 "	trace "	...
66.0	35.50	203.78

The average of the ore, using these data, is slightly over 3 oz. per ton. If, however, the fifth sample, which is very high, is eliminated, the average drops to less than 1 oz. per ton, while, on the other hand, if the high sample is retained and the last two poor places are omitted, the result is affected to a much less degree, the average then being about 3¾ oz. per ton.

In re-sampling these apparently very rich spots, it will be found that three contingencies may occur; the result may be corroborated or it may be proved to be accidental, while, should every high assay be found incorrect, then there is a third possibility to be considered, namely, whether the samples have been tampered with.

If out of a considerable number of high results not one is confirmed, then it is time to look around. If some are confirmed by re-sampling, while others are not, then, obviously, the values in the ore are erratic, and a correction must be made for each case; if most of the high results are approximately repeated by the second sample, then it is evident that the first sampling was correct, and that the ore is very rich in spots; intermediate samples must be taken, and when this is done the data for calculations will be complete. It is wise to take intermediate samples, both when the high assays are wholly, and when they are only partially, confirmed.

It has been argued by certain engineers that the mill or smelter always fails to confirm the very high assays occasionally obtained in sampling and that, therefore, they should be omitted as a factor of safety. This is not a fact. Exceptions occur. In the case of the Argentine lode of the Tomboy Mining Company, at Telluride, Colo., a careful sampling of a block of ground, at intervals of 10 ft., yielded an average of $7 per ton, all rich spots carrying visible gold being avoided. This work was done by an inspecting engineer of recognized capacity; nevertheless, the actual mill returns were $28 per ton. Nor is this inexplicable when the nature of the ore is considered. The writer saw a piece weighing 25 lb., yellow with finely disseminated gold, so that it contained $100 worth of the native metal, which came from the breast of a level on a certain day—and the very next day the foreman's sample from the face of the same drift, which had been advanced two or three feet during the interval, yielded only two-hundredths of an ounce of gold per ton. The Pandora vein, in the neighboring Smuggler-Union mine, affords another exceptional case; the mill results are usually higher than the assays, and this is explained as being due partly to the greater hardness of the rich ore, but chiefly because the gold occurs almost entirely in coarse particles which, being readily visible, are apt to be carefully shunned by the conscientious sampler. These instances are corroborated by the thoroughly experienced managers of the properties quoted. It remains to add that while it is true of the veins specifically mentioned, that the assays are usually lower than the mill returns, such is not the case with the Tomboy lode, which is near the Argentine, nor is it true of the Smuggler lode, which is intersected by the Pandora in the Smuggler-Union mine. The above are, however, well-authenticated exceptions, which serve effectually to undermine a generalization which is the last resort of a timid engineer. Not that the factor of safety is to be discarded, quite the contrary; in all engineering such a precautionary measure is imperative, but do not introduce it disguised; face the facts, state them, and then introduce your factor of safety without any circumlocution.

Why do sampling results differ from the mill returns? In the unusual instances, just mentioned, the difference was traceable to conditions which are relatively rare, but are always within the range of possibility. There is no doubt in my mind that the usual experience of finding the mill-extraction below the estimates, based upon sampling and assay, is due to the fact that rich ore is ordinarily in the softer, more crumbly parts of a lode, or it is associated with sulphides which are not only easier to break than quartz, but they also make a shining mark which invites the blow of the moil and hammer. This aspect of the inquiry emphasizes the weak factor in sampling, it is not absolutely mechanical, a man and not a machine does the work, and the results partake of that liability to error which is essentially human.

It may be asked, in conclusion, what course should be adopted with high assays when it is not possible to resample? Frequently, the samples are not assayed near the mine, but are taken, or sent, by the engineer to a reliable assayer living in a distant locality. Time, an element in all business matters, may prevent the engineer from returning to the mine to take further samples. This is a dilemma not infrequent in current practice. Judgment and experience must decide. The relative frequency of high assays, the degree to which they affect the final estimates, the character of the ore, the results of sampling as compared to the actual recorded average of the mine, the character of the work done by the engineer and his assistants; these and similar factors will determine the decision. One cannot lay down rules to direct any man's judgment.

It may be permitted to say that if you are uncertain of your results, don't use them. Do not let yourself be hurried, either by your client or, as is more probable, by the vendor, to committing yourself to a decision based upon data the accuracy of which, in your own mind, is in any doubt. *It is better to be sure than sorry.*

THE POSSIBLE DISCREPANCIES BETWEEN SAMPLING AND MINING.

In sampling the workings it is necessary that the engineer should have an eye to the manner in which the mine is being worked. It is useless, for instance, to sample two feet of vein-matter without any regard to the fact that in stoping it is the practice to remove a width of four feet. Unless judgment is exercised, the samples are apt to represent cleaner ore than the output of the mine, so that the estimates based upon them will be misleading. The material sent for treatment to mill or smelter may differ from the ore composing the lode as seen in the mine, in several respects. Thus:

A. The lode may be smaller than the minimum width removed in stoping, so as to necessitate the mining of a certain portion of barren rock.

B. The lode may be as wide as the convenient size for stoping, but it may have a casing of soft rock, which breaks down with the ore and becomes mingled with it so as to increase the tonnage and diminish the average yield per ton.

C. The lode may be built of one or more streaks of rich ore irregularly distributed through it, so that in stoping it is necessary to break down a large and variable width.

In the preliminary trip through the mine the engineer will be able to find out by observation, together with the information obtainable from either the foreman or the manager, how the ground is being worked, and how the ore is being handled. If he does not secure these data at the preliminary examination he will light upon them in the course of his investigations into costs, for without them the relative expenditures at mine and mill will be contradictory, if not unintelligible.

Concerning the conditions first mentioned, under the heading A, it is obvious that the width broken in stoping has a minimum, which in ordinary practice varies according to the method employed; that is, with hand labor a width of two to three feet will ordinarily suffice; while at least three to four feet is necessary when machine drills are used.[1] In both cases this minimum width will be exceeded if the rock is very hard or if it breaks along easy lines of fracture, which cause more rock to be taken down in blasting than is absolutely required for mere convenience in working. If the streak of ore is less than the width of the stope there will be, inevitably, an admixture of waste, except in the rare cases where it is practicable to strip the pay-streaks, that is, stope the country without removing the vein, which is subsequently taken down separately. This method, which is covered by the Cornish term "resue," is excellent when the vein of ore is narrow, but it depends for success upon the ore being closely attached or "frozen" to one of the vein walls, so that it will not be shaken down when the adjoining waste is shot away. In many mines in Colorado, Montana and Idaho, especially in the case of narrow streaks of very rich silver ore, it is not unusual to spread canvas or sacking along the floor of the stope and then break down the ore upon it, which in this way is kept free from admixture with waste, and can be sacked with-

[1] A small (2¼-in. cylinder) drill usually requires a stope of 3½ to 4 ft. in width, the large air drills (with 3½-in. cylinder) take from 4½ to 5 ft.

out any sorting. The canvas is covered for protection with 6 by 3 by 12-in. timbers. In such a mine as this the sampling of the vein itself would give data which closely approximate the actual returns from ore sent away to the smelter.

When it is not possible to mine the ore separately from the waste it is usual to pass it over the sorting tables, where the waste is picked out by hand. In the determination of the percentage thus eliminated lies the difficulty of getting the proper relation between the assays of the ore as sampled and the value of the material as sent to the reduction works. Unless this is determined, and the sampling is corrected in accordance, the figures of the engineer will not harmonize with the results of future operations. The most practical way to find out the percentage sorted out is to measure the ground stoped during a given period, and, knowing the tonnage extracted from such a particular block of ground, to determine the average width of clean ore actually obtained from that block. If the average width of the vein is fairly consistent, one can, from these data, deduce the amount of waste which gets mingled with the pay-streak and then correct the assay returns, from sampling, accordingly.

However, gold-veins are rarely uniform in width, and, moreover, any given mine may contain several lodes, the output of which is not kept separate. In such localities as Kalgoorlie and Cripple Creek, where the veins are rich, erratic, and so diffuse in their mineralization as to make it compulsory to break down a great deal of waste in extracting a small width of clean ore; where, also, the large mines include within their boundaries two or three distinct lodes of variable width and richness, it becomes an extremely difficult task for an engineer to determine, within the short period of his inspection, to what degree the vein-stuff is mixed up with waste. An example will emphasize the matter under discussion. Take a lode or series of lodes having an average width of one foot of four-ounce ore. Assume, as is usually the case, that a width of at least four feet of rock is actually removed in mining, so that one foot of ore is shot down with three feet of waste. If you sample the vein alone you get an average of four ounces of gold per ton; if you sample the four feet of stoping width you get an average of one ounce per ton, unless there happen to be one or more stringers of ore outside the main pay-streak, not rich enough to be worked on their own account, but near enough to the vein proper to be included within the ground which is removed. In this case the average may become slightly higher than the figure which is based on the supposition that the extra three feet is barren material. That is a detail. The point to be emphasized is that the product of the mine will be more than the tonnage based on one foot of ore and considerably less than the tonnage based upon the stoping width; more is broken than one foot, because mining does not copy sampling methods, and less is shipped than four feet, by reason of the sorting which intervenes between stope and smelter. Similarly, as to the average value, the production of the mine will average less than the four ounces in the clean ore, but more than the one ounce which is the assay value of the stoping width.

At Cripple Creek, and in other districts where the costs of transport and treatment are high, this four feet, or more, of ore is sent to the ore-house and is sorted by hand. It may have been first culled underground, the large pieces of waste being retained on the stulls. This is the practice in most mines. In any event, a certain proportion of waste is thrown out, and it is only the remainder that is milled or marketed. What is that proportion which is taken out?

Here lies the difficulty which has been at the bottom of many an erroneous estimate. If the engineer is pressed for time, by reason of agreements made between the buyer and seller of the mine, he will not have the opportunity to conduct such tests as would give him the requisite data. The management is apt to have loose ideas on the subject; the ratio of waste eliminated to clean ore actually shipped will vary from week to week, just as the different stopes underground will change from time to time, so that it is rarely possible within the period of a brief examination to get, save at second-hand, at the percentage which so seriously affects all calculations. Under these conditions the only thing to do is to state the results just as they are obtained, explaining how they are obtained, and then make the correction which judgment dictates. If the vein has been sampled by itself, then an addition for the unavoidable admixture with waste must be estimated, the amount being based upon the observation both above and underground. If the sampling has included the full stoping width, then a similar correction must be made for the amount of material subsequently removed by sorting, otherwise the statement of sampling returns may prove unintelligible, it being not uncommon for the average value of the ore as stoped, before sorting, to be less than the total working costs.

However, except in the unpleasant circumstance of limited time due to the unavoidable exigencies of business, which unfortunately do often hamper, hinder and obstruct the engineer in his professional work, it is possible to arrive at the ratio of ore and waste, and, therefore, to formulate accurate estimates. It requires time and it needs money, but in the examination of large mines nowadays it is appreciated by financiers and syndicates employing first-class engineers that they must make provision for plenty of time and money in order to get good men to do good work. This may seem a digression, but it vitally affects the consideration of this branch of the subject under discussion.

When, therefore, conditions do permit of every precaution, the engineer will cause the ore, as it comes to the surface, to be weighed, he will get the weight of the clean ore after sorting, and he will check this with the weight of the material which goes over the dump. He will also take samples of the dump to correct his estimate of the average values. The weighing and sampling will, of course, be done by his own men. He will also take careful note of any waste which is retained underground, as is usually the case in a well-managed mine. If this is done during the space of a month or so, which is the minimum period permissible for an important examination, he will have data enough to enable him to correct the results secured from the sampling of the mine. In the suppositious case quoted above, the one foot of four-ounce ore would be mined (and sampled) with three times as much waste, one-half of the material thus broken would be sorted out at surface, and with it would go some of the fines, so that the net result might be about two feet of ore assaying 1.75 oz. and two feet of waste assaying about 0.25 oz. per ton.

These final estimates should be borne out by the future record of the mine. As a safeguard, however, the engineer ought to state in detail, in his report, how he arrived at his figures, lest, later on, an ignorant directorate or an unscrupulous manager should either work more than a proper width, in order to get an increase in tonnage, or mine only the richest portion of the lode with a view to a brief period of inflated returns. Such things have happened, and honest men have been drawn into the blame which followed.

Coming to the consideration of the second point, specified under B, it is evident that here also there is room for error. In most lodes of gold-bearing quartz, where sorting is out of the question on account of the low grade of the ore and the uncertain dissemination of the gold, it is not possible to break the ore in the stopes as clean as it is broken in the course of sampling. Should the lode be free from an admixture of country it is, nevertheless, rarely practicable to stope it without bringing down some of the encasing rock. This is slight in some instances of very well-defined quartz veins, large enough to admit of a full-sized stope and so separated by selvages from the wall-rock as to come clear away. In most instances, however, the stoping will include a large proportion of waste, and when it happens, as is not infrequent, especially with big, generous ore-deposits, that the lode throws out branch-veins or is enriched by feeders, then it will be found that there is a very considerable admixture of comparatively barren rock.

Circumstances such as these, overlooked or underestimated, have been at the root of the differences between the estimates of capable engineers and the subsequent record of the mines they have reported upon. Managers, as a rule, like to emphasize the clean-cut character of their operations, and are apt to accentuate the fact that the ore "breaks easy" and free from wall-rock. Moreover, in all mining, there is an element of the unexpected, which in this case takes the form of the breaking away of "slabs" of wall-rock, the admixture of large pieces of "casing," the occasional "horse" or intrusion of barren rock amid a width of ore, and other contingencies, all of which tend inevitably to an increase of tonnage and a diminution in the average value of the output. One must look for these features in a mine and obtain data sufficient to warrant an estimate of their perturbing influence upon the accuracy of those calculations which are at first based solely on the results of sampling.

The third subdivision, C, includes a large proportion of the big low-grade lodes from which so much of the metallic wealth of the world is derived. An examination of a mine is usually confined to those workings which are confessedly profitable or likely to become so. The non-payable workings are neglected. In actual mining, however, a level or a raise is apt to be carried forward through poor ground in the hope of encountering better ore, and it is not uncommon to remove blocks of unprofitable ground lying between good stopes because of practical convenience in working. In this way there is a tendency to vitiate the results of sampling, if not corrected in accordance with a recognition of such indubitable facts. Moreover, in the working of large deposits of low-grade ore, where the width to be removed is not determined by well-defined boundaries, but is left to the arbitrament of the assay, as a consequence of a diffused impregnation of ore, there is a tendency to increase the stoping width. The result of a steady diminution in working costs, due to better management, improved equipment and more favorable economic conditions, is to permit of the exploitation of poorer ores. This leads to the utilization of neglected stopes, previously considered unprofitable, and the enlargement of the stoping width so as to include more and more of the outer poorer edges of the lode. An increase in the capacity of the mill is usually followed by a drop in the average value of the output. On the Rand this tendency has become very marked; thus, for example, most of the original estimates of the life of particular mines were based on ore-reserves calculated upon the basis of a certain width of 'banket,' but since the substitution of rock-drills for hand labor it has been found advisable, consequent upon observation and experience, to increase the stoping width by as much as 50 per cent. This increase has necessitated the breaking of a larger amount of barren rock, but a compensating factor has been found in the introduction of revolving circular tables, which facilitate the picking out of the waste by natives.

These are considerations which the engineer must keep in mind. He is not expected to write next year's almanac, but if he is to be justified by the actual record of the mine, his report must be aided by some of that farsightedness and shrewdness which is necessary to a successful meteorological forecast.

ESTIMATION OF ORE-RESERVES.

It has been well said that "if you want to arrive at intelligible issues—not to say conclusions—in any discussion, begin by settling the meaning of the terms you are going to use."[1] This is particularly necessary in discussing a subject which suffers from the want of definition. "Ore in sight" has become one of those nebulous phrases which are only noise and smoke. It is imperative that we have a clear conception of the fact signified

[1]Dr. Thompson, late master of Trinity College, Cambridge.

by the technical terms we employ; when we find that they are robbed of sense as soon as we dissect them, it devolves upon us to discard them and seek for better ones. "Ore in sight," as used to describe the ore-reserves of a mine, is, if taken literally, a contraction in terms, and, if taken otherwise, it has an elasticity which has caused many to stretch it until it has become so indefinite as to include the ore which is beyond even the most imaginative vision.

In order to express the results of careful sampling and estimation by a phrase which will at once convey its meaning, even to the untechnical, I would suggest "ore in reserve and ready to be broken," or "ore ready for stoping."[1] This would cover those parts of a mine which have been so cut up by systematic workings as to permit of very close calculations. Next would come the blocks of ground incompletely developed, but known to carry ore, which, in character and persistence, are similar to the main portion of the mine. These could be covered by the term "probable ore-reserves." Beyond this point a careful engineer will not go, avoiding "possible ore-reserves," or any similar phrase, as a snare of the devil, because of the great likelihood that his client, or the shareholders who may follow, will disregard the qualifying adjective and commit him to a meaning which he did not intend to convey. When it comes to the chances of development, itself a most important part of the engineer's exercise of judgment, it will be best to include the consideration of this aspect of the inquiry under the paragraphs which deal with "the future prospects of the mine."

That is reserved which is stored for future use, therefore that which is to be used forthwith is not in reserve, from which it follows that by "ore-reserves" is meant such bodies of ore as are kept back for the present with

[1]This discussion of terms was written some time ago, before Mr. Argall brought forward the sensible suggestions which appeared in THE ENGINEERING AND MINING JOURNAL of February 14, 1903. They will be found on page 76 of this book.

a view to future use, when those are exhausted which are now being stoped. A mine which is being stoped at a rate so rapid in ratio to its development that it has, at any given time, only enough ore to keep the mill going for a few palpitating moments cannot be said to have any "ore-reserves." The idea of the latter includes a reservoir of supply not to be exhausted at short notice. As a consequence of these considerations it is obvious that the amount of ore which warrants being entitled "reserves" will depend upon the relative size of the reduction plant which is attached to the mine.

At the outset it is permissible to quote the famous dictum of President Cleveland, in referring to the tariff: "It is a condition which confronts us, not a theory."[1] Any attempt to establish uniformity of procedure in the estimation of ore-reserves is bound to break down because it disregards the inevitable diversity of the conditions which obtain in mining. Mines differ, as men do. A safe presumption in one case is a hazardous guess in another. During a recent discussion of this subject it was suggested that it was desirable for mining engineers to agree upon certain general rules as to the allowance to be made in estimating ore. You might as well sign an agreement upon the percentage of trust to be placed in human nature. There are mines, the ore-bodies of which are of such a character that it is safe to predict their persistence for several hundred feet; there are others where the lode is so erratic that ten feet is a dangerous assumption.

Examples will serve to emphasize the range of variation. On the Rand a bedded vein of gold-bearing conglomerate extends for a great distance, and over portions of its known length it maintains an average tenor so fairly constant that "the values of unworked portions may be closely calculated from the results achieved in adjoining developed mines."[2] In any given mine—to narrow the assumption—it is quite safe to calculate

[1]*Messages of the Presidents*, Richardson. Vol. viii, p. 590.
[2]G. A. Denny. *The Deep-Level Mines of the Rand*, p. 119.

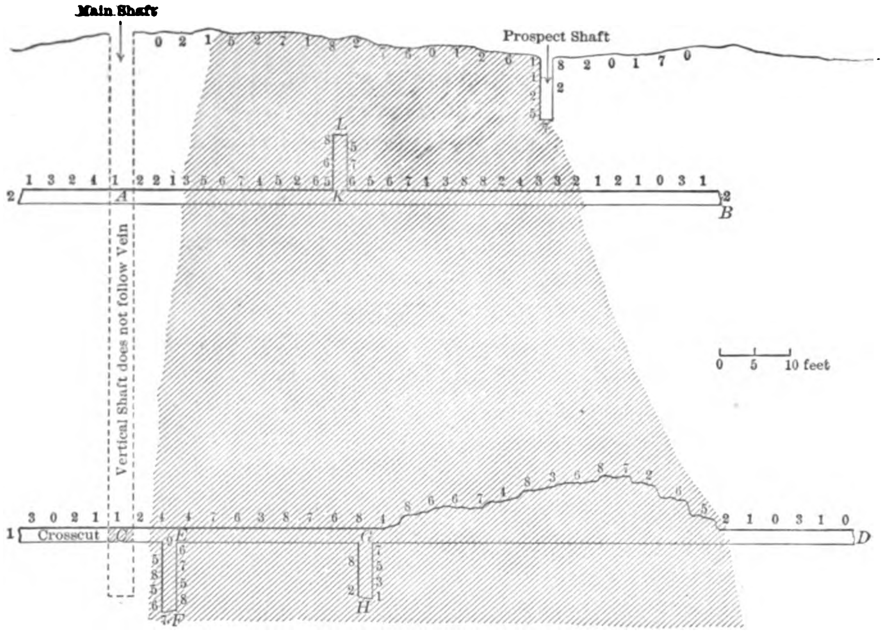
the average value of the ore in a block of ground, say, 300 ft. long and 150 ft. high, that is, after this block, 150 by 300 ft., has been sampled at intervals of, say, 10 ft., on every one of the four sides of the rectangle. This would be the ideal "ore in reserve," a thoroughly sampled block, not too big to vitiate the assumption of a certain uniformity in value per ton. In contrast to this I would quote such mines as, for example, the Seven-Thirty at Silver Plume, Colorado, or the Yellow Pine, near Boulder, in the same State, both of them mines which have been at some time richly productive, but with a distribution of value, in silver chiefly, so varying, so spotty and uncertain, that careful sampling, at regular intervals of even less than 5 ft., around the four sides of a block only 50 ft. square, would afford the basis for an estimate which at its best would be only a reasonable guess. Each mine must be judged on its merits, in each instance the conditions vary, and while there may be a general similarity of method in getting at the various facts, there never can be any cast-iron uniformity in the nature of the inferences deducible from the facts. Experience, silvered with age, is the presiding judge, and will decide whether this or that piece of evidence is relevant or not. Nor is there any room for pessimism or for optimism; one is as much out of place as the other; indeed, it is not too much to say that while a sanguine temperament will lead sometimes to exaggerated expectations, it is equally true that an over-cautious hesitancy is to be condemned. Occasionally, an engineer in his effort to avoid risking his own reputation is apt to lean toward a timid conservatism which sacrifices the interest of his client. He is engaged to determine the facts, in the first place, and then to apply his best judgment to them. If the facts are insufficient, let him say so; if they are sufficient to warrant a decided opinion, let him enunciate it clearly, to the end that his client may get the maximum benefit of his investigations.

"The proof of the pudding is in the eating." The exact profit to be won from a certain block of ore-bearing ground is best known when it has been mined and milled; even the most uniform ore has its spots of greater and lesser richness; the best estimate is therefore only a close approximation based upon the doctrine of averages. Nevertheless, if such estimates are occasionally wide of the mark it is not merely because of *la malice des choses,* that essential contrariness of things which will baulk even the best of engineers, but more frequently it arises from the disregard of the A, B, C of proper procedure and a judgment vitiated by financial participation in the undertaking itself. I am not of those who believe that the sampling of a mine is the one decisive factor in the diagnosis of it, on the contrary, I hold that as evidence it is crucial or merely collateral, according to the circumstances of the case, which may depend upon the past record of the mine, its future possibilities, the geological environment, economic conditions and other factors of primary importance.

INFERENCES FROM SAMPLING.

When the sampling has been thoroughly done, the engineer is in possession of many important facts. If he is a novice he will have learned the assay-value of the ore at each of the spots he has sampled and he will have learned little else.

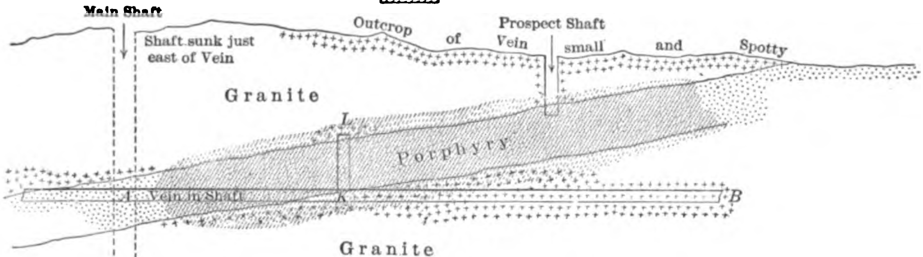
Nothing illustrates so well the proverb that "a little knowledge is a dangerous thing" as the direct inferences from the results of sampling. To emphasize this statement, I will take an instance which is founded on fact. In Fig. 5 you have a longitudinal section of a small mine, which has been apparently well opened up. The shaft is vertical, and does not follow the vein, which inclines to the west. The levels to the north have found nothing, those to the south (A B and C D) have cut through ore which is also explored by a raise (K L), and two winzes (E F and G H). At the lower levels, stopes have been started and the 'backs' make an excellent showing, as the figures indicate. The latter are not expressed



SECTION OF WORKINGS EXHIBITING THE RESULTS OF SAMPLING.

FIG. 5.

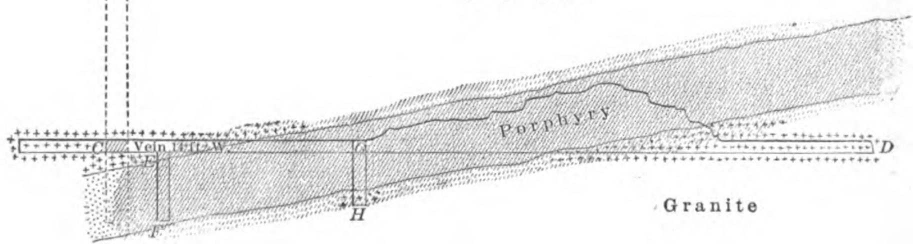
Ore estimated



SECTION OF WORKINGS SHOWING THE GEOLOGICAL FEATURES.

FIG. 6.

0 5 10 feet.



Granite Porphyry Ore Bodies

in any particular unit, but it is to be supposed that zero means barren, 2½ means pay-ore and so on, up to 8, which marks rich ore. The results are indicated on the section. The inference, as to the amount of ore in the mine, is exhibited by the cross-hatching.

In arriving at this estimate the novice is guided by his sampling alone; he has failed to take note of the geological features. It may happen that the superintendent of the mine, an old, practical miner, we will suppose, has told him that the ore is fairly uniform within the limits of the shoot, and that while the rock does indeed vary a little in places, this variation does not seem to affect the general distribution of values. Or, again, it may be, as happens often, that the man in charge of the mine is honest, but not honorable, and, instead of committing himself to such statements as the foregoing, he keeps discreetly silent, or, under cover of appearing to refrain from influencing our young engineer,[1] he absents himself while the sampling is in progress, and leaves his shift-boss or some other underling to do the talking. Perhaps, indeed, those in charge of the mine really do not appreciate the true condition of affairs, and the engineer is deceived by an oversight which will appear almost excusable. However, the mischief is done, the mine is taken over by a financial syndicate or a mining company. Before the business is actually consummated, another engineer, representing another financial interest, is sent out to make an examination. We will suppose that this man is of greater experience than the last; he is, moreover, familiar with the geological structure of this particular district or of another similar to it. He proceeds to sample. The accuracy of the previous sampling is confirmed, but in the course of his investigation he has noticed that the country is not uniform, and that there

[1]I have supposed the blunder to be due to youthful inexperience, for this is the least blamable, but as a matter of fact, blunders of this kind are due to ignorance and are frequently made by older men of the kind described as "thoroughly practical," where the particular emphasis on "practical" is indicative of utter lack of training or such technical education as an engineer requires.

are two different rocks exposed by the workings. One is obviously granite, the other he cannot label accurately without a microscopic section, but it is evidently an eruptive which has intruded into the granite; so, on account of its speckled appearance, he applies the term 'porphyry' to it, and when the sampling is finished he spends a few days in carefully examining the workings with a view to getting an idea of the structural relations between these two rocks. The results are set down graphically, and he obtains the information illustrated in Fig. 6. By examining this section, side by side with Fig. 5, it will be seen that his inferences are warranted. The consequences are surprising. He discovers that there is no continuous ore-shoot from the surface downward, but that there are two comparatively small lenticular ore-bodies which occur where the vein cuts through the porphyry sheets, and only in those portions of the porphyry where certain cross-veins have exercised an enriching effect. When the vein gets into granite it becomes poor, and, moreover, it pinches, a fact which the sampling did not sufficiently emphasize. The ore-reserves are cut down to a fraction of the previous estimate, and the future prospects of the mine are considered most uncertain, because the ore already found is due to local structural conditions which are unlikely to recur.

Another kind of error may be instanced. It is more frequent in placer mining than in the estimation of ore in lodes. Fig. 7 represents the cross-section of a deposit of tin gravel in an old river channel now capped with basalt. The deposit was sampled through shafts which cut right down to the 'gutter,' 180 ft. deep, below the basalt. In this sampling the gravel was taken all the way down the shafts and mined together, so that each shaft yielded one large sample. From the weight of this and that of the resulting grains of tin, after panning down, the percentage was calculated. The estimate of quantity was based upon the length of channel, within the boundaries of the property, multiplied into an inverted triangle, A B C, the base of which was the top width of the deposit and the apex the 'gutter.' The cubic yards thus obtained gave an approximately correct result as to quantity of material, but the estimated average content was all wrong, because the method of calculation disregarded the fact that the richest stuff was concentrated at the lowest end of the triangle, and actually formed a very small proportion, in weight, of the whole. Subsequently, the ground was re-sampled. The total depth of 180 ft. was, in the case of each shaft, subdivided into sections of 30 ft., except the last 30, which was further divided into two portions, one of 20 ft., and a lowest

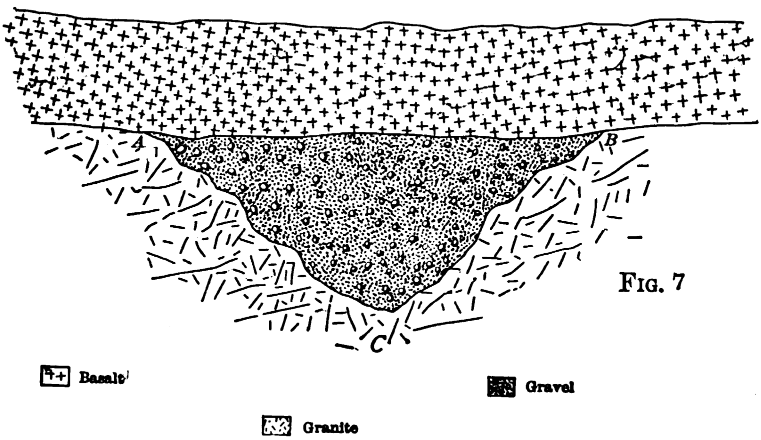


FIG. 7

of all, only 10 ft. thick. The first 30 ft. was found to be almost barren, the next 30 ft. assayed 0.2 per cent. of tin, the next 30 ft. 0.28 per cent., and so on, increasing gradually until the last 10 ft. was reached. This was very rich, 1.5 per cent., on account of concentration in the 'gutter' or bed of the channel. Each layer was calculated separately as to quantity and average contents, giving results which proved the bottom to be very profitable, but difficult to work on account of want of gradient for hydraulicking operations; while the uppermost portions of the deposit were found to be too poor for profit, but yet requiring handling in order to get at the lowerlying part of the gravel.

The method first described would have given a very much exaggerated idea of the cubic yardage and a false notion of a uniformity of value, besides ignoring the working difficulties to be encountered in the extraction of the tin from the successively deeper layers of the gravel. This is very much like the sampling of a vein in a prospect shaft where the samples are taken every 10 ft. and are allowed to fall to the bottom where they mingle confusedly and eventually form a "large sample," the weight of which is mistakenly supposed to give assurance of the accuracy of the average deduced from the subsequent assay.

It is not necessary to cite other instances of this kind. Happily, they are rare. The real work of good judgment usually commences in the estimation of future prospects. Mines are very rarely bought merely for the ore proved up by complete evidence; the attractive feature is, as a rule, a speculative enhancement of value likely to arise from further discovery. This is where the trouble begins.

THE FUTURE PROSPECTS OF A MINE.

There is room for the exercise of a wonderful lot of common sense in the judgment of a mine. Science, after all, is, as Huxley himself said, "organized common sense." If you have been walking along a road which has been straight and level for five miles you are unlikely to go wrong in supposing that it will continue straight and level for another half mile, even though the foliage prevents you from seeing more than a hundred yards ahead, but if you have proceeded along a road for a half mile or so only, it would be deemed foolish to predict that the road will maintain the same gradient and direction for five miles further. Thus, in estimating the persistence of an ore-body you may be justified in counting upon its continuity for another hundred feet if the ore has already persisted with some degree of uniformity for five or six hundred feet downward, and so, on the contrary, you will be playing with Providence if you assume a continuation for several hundred feet on the part of an ore-shoot which has as yet been traced for only 50 ft. from the surface. In this respect the mines of the Rand afford a striking contrast to most precious metal mines. The 'banket,' in comparison with the ordinary type of gold-vein, has the persistence and uniformity of a coal-seam, and explorations on a large scale all over a very extensive region will warrant an engineer in making assumptions which would be ludicrous in California or Colorado. Yet, even under these exceptional conditions, such general evidence of continuity, when applied to an individual mine, must be amenable to the particular testimony obtainable in that particular mine or in the workings of its immediate neighbors. In most gold-mining districts there is such an absence of uniformity in the structure and behavior of gold-bearing lodes that it becomes imperative to rely upon the particular testimony afforded by each mine. Such testimony, however, must be read in the broad light of experience. For this reason the estimates of ore likely to be opened up by further development will be more nearly correct on the Rand than similar calculations made by the same engineer elsewhere. Another distinction obtains; a precious metal mine in Colorado or California, by reason of mining laws which give the owner of the outcrop the right to follow the vein indefinitely in depth, has a future which is not confined to the narrow limits of mere acreage, such as is imposed in the Transvaal, in Australia, Mexico, etc. This renders the future of the American mine more speculative, while at the same time it lays upon the engineer the responsibility of appraising possibilities which are quite beyond the limits of ascertainable fact. It is no solution of the problem to say that such possibilities have no assessable value, for to adopt this attitude is to disregard the entire history of precious metal mining in the Great West, and the engineer who rests content with the evidence which is before his nose will prove but a disappointing, and often misleading, adviser to an enterprising client.

In arriving at general conclusions concerning the persistence of an ore-body in a mine, the engineer may have several guides, namely, the internal evidence afforded by the behavior of the ore-body in the ground which he has examined, the collateral suggestions afforded by the behavior of other ore-bodies in the same mine, the general evidence obtainable in other mines within the same region.

When the value of a mine centers upon one large ore-body, rather than several, there is no opportunity for inferences founded on similarities of behavior. The engineer is compelled to seek for internal evidence. If the sampling has been properly conducted and the results have been set down on the longitudinal section of the workings, it will be found that the ore exhibits local variations from which certain deductions are possible. The relatively richer parts of the ore-body may be so distributed as to indicate mere absence of uniformity, and nothing more, but, as a rule, the indications will go further and suggest either that the ore-body is becoming richer with increasing depth or poorer in the same direction, or that there are successive zones of richer or poorer. Again, the lode may be as rich as heretofore, but a change may be apparent either by way of a shortening of the ore-shoot or of a narrowing of the pay-streak. For all these possibilities one has to search amid the tangled mass of evidence.

One or two instances will serve to illustrate such possibilities. In the San Juan region of Colorado the prevailing geological formation is a volcanic breccia, of Tertiary age, built up of fragments of andesite, which are arranged in neatly horizontal layers. The veins cut through this rock without, commonly, causing any very big dislocation. In these gold-bearing quartz veins there occur ore-shoots having a pitch which is usually not far from the vertical, and while such ore-shoots may be worked out in their entirety so as to exhibit an unbroken continuity in the stoping, nevertheless, to those who are observant of the variations in the grade of the ore, as recorded by daily assays or weekly mill returns, it is very clear that such variations coincide with the changes in the country; that is to say, the ore-body will be characterized by nearly horizontal bars of enrichment which are traceable to the effect produced upon the vein by the particular layer of breccia through which it is passing at a particular horizon. My observations lead me to suppose that the composition of certain layers of the fragmental volcanic rock is responsible for the effects noticed, and that the layers which have the finest texture are those which are the most beneficial, for reasons outside of the present discussion. One example will suffice. In Fig. 8 it is seen that a series of adits penetrate a steep mountain which is entirely composed of andesite breccia. The lowermost adit goes through an average of 2½ ft. of 6 dwts. of gold, which is, in the district where the mine is situated, rather low-grade. The first portion of the level and the end of it pass through barren ground, so that there is some evidence of the existence of an ore-shoot of this low-grade stuff. In the stopes there is no change to record until the next level overhead, No. 2, is approached. A raise connecting with this level passes through 8 dwt. ore. No. 2 adit makes a much better showing, and averages, fairly uniformly, 11 dwts. for an average width of 4 ft. Here also the level passes out of ore at a point nearly vertically over the corresponding impoverishment at No. 1. The stopes above No. 2 give, at first, results as good as the drift, but in going upward they show a marked falling off, so as to average one-half the results given by the No. 2 level. At No. 3 the average of the level is only 3½ ft. of 4-dwt. ore; this is doubtless the reason why the drift was not extended to the limit of the shoot. A raise put up from this level is in poor ground until within 50 ft. of No. 4; then marked improvement sets in. This is confirmed by the results from the No. 4 adit, which gives an average of 3 ft. of 10-dwt. ore. This good mill-stuff, however, does not extend much above the level, as is proved by a raise, which gets into poor ground.

Fig. 8.

Showing Results of Sampling.

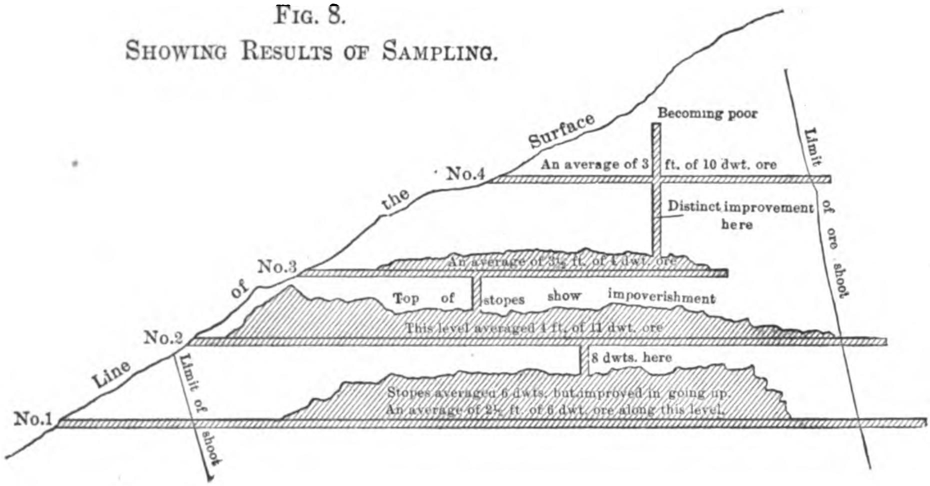
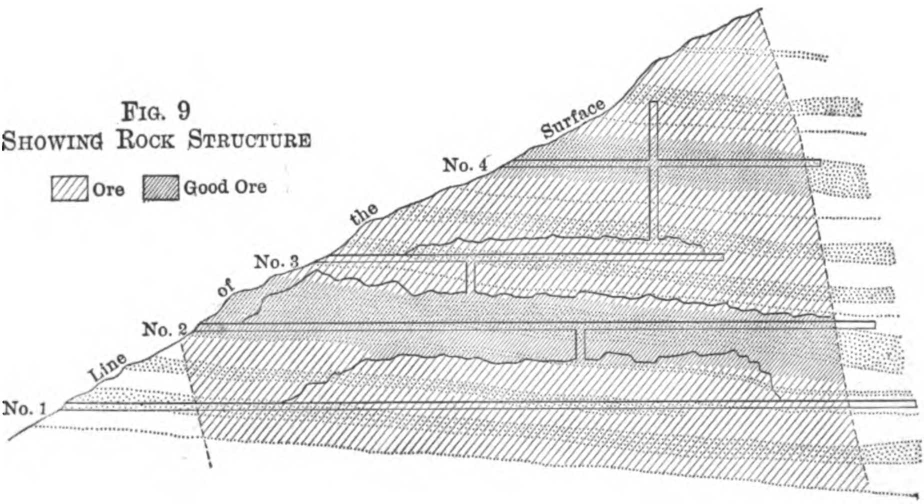


Fig. 9

Showing Rock Structure



These data are perplexing and indicate an alternation of values which renders any estimate very hazardous. When, however, the geological structure is investigated, there is found to be a relation, between values and structure, which illuminates the entire problem. In Fig. 11 there is given a section, on the plane of the vein, which exhibits the position of the series of layers through which the vein cuts. This helps to explain the results shown in Fig. 9. The zones of enrichment penetrated by adits No. 1 and No. 4 coincide with two layers of close-textured tuff, or fine-grained breccia, laid down during the intermittent violence of volcanic eruption. The intermediate, overlying, and underlying beds of breccia are coarse, and, for some reason which does not concern the present inquiry, they are less favorable to ore-deposition than the occasional layers of tuff.

In this instance the evidence was very clear; in other mines situated in the same region it is not practicable, on account of the decomposition of the enclosing country, to establish the relationship so clearly, but it is a matter of experience that notable variation in both the width and value of the lodes does occur in a similar nearly horizontal direction. The understanding of it is, therefore, a clue to many apparent vagaries in the distribution of rich ore.

In the case of a mine which contains several ore-bodies there are many useful suggestions to be obtained from a comparison of their characteristics. Careful investigation will lead sometimes to the detection of peculiarities applicable to the general occurrence of ore in that particular mine. The longitudinal section of the stopes warrants the close study given by a general to the map of the region which is to be the scene of his campaign. Stope-maps are not always correct; sometimes they are incorrect to a very misleading degree. A few measurements, at least, should be made to test this point, and occasionally, when the general accuracy of the surveys warrants a doubt, it is a good precaution to make one's own map of the mine, either personally, or by engaging the services of a reliable surveyor. The conditions are so diverse that it is impossible to give a typical illustration, but, by way of suggestion, I will append an example of inferences derived from a study of the old workings of a mine. It is a small mine; for, after all, the most perplexing of problems is a 'prospect,' and it is found in practice that the greatest mistakes and the exercise of the keenest judgment are alike exhibited in the appraising of the uncertainties of an undeveloped mine; therefore, the size of the property chosen as an illustration scarcely requires apology.

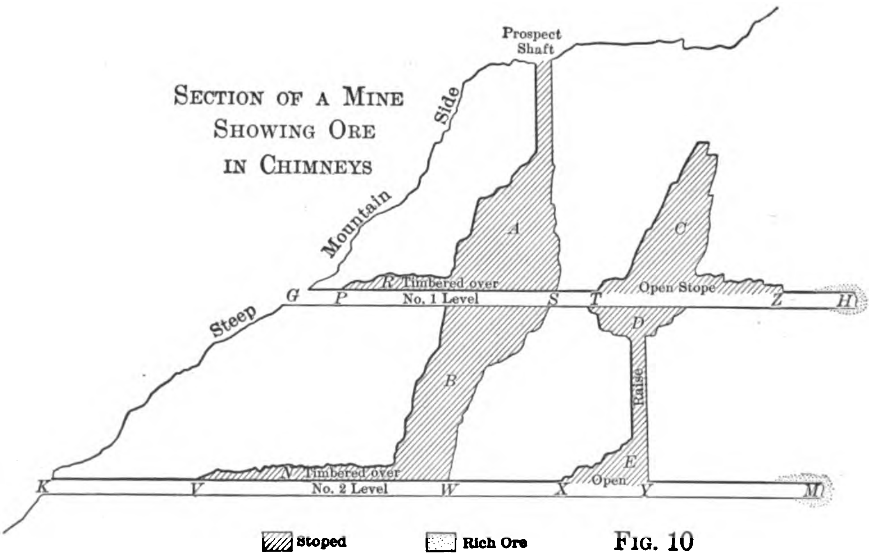
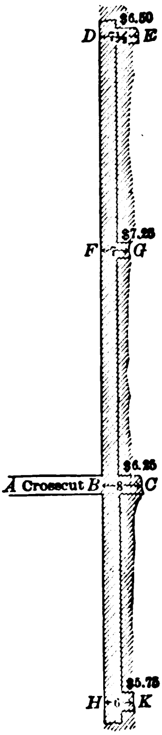


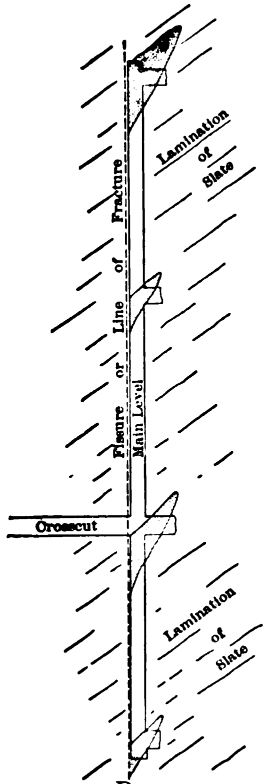
Fig. 10

Fig. 10 represents a section of the workings. These consist of two adits, on the vein, together with a discovery shaft, which joins the upper level (G H), and a raise connecting the latter with the lower level (K M). The problem is to determine what weight should be given to the occurrence of a good width (say, 4 ft.) of very rich ore (say, 5 oz. of gold per ton) in the ends (H, M) of the two levels. In such a case it is most important to investigate, with thoroughness, the mode of occurrence of the ore-bodies previously encountered in the mine. This is not always easy; old workings have been allowed to cave or the ground is heavy, and they are carefully timbered so as to impede examination. Sometimes this is intentional. In the case cited the upper level appears to carry one continuous body of ore from P to the breast at H, with a small comparatively barren interval S. T. The timbering obscures the fact that the first half of the stope P S is only a cutting-out stope, which was worked for the purpose of testing a low-grade portion of the vein; the same applies to more than two-thirds of the stope V W, at the lower level. Similarly, while the timbering between T and Z indicates a good length of stope, as a matter of fact the innermost half of this is little more than a 'cutting-out stope' in comparatively poor ground. The truth is, the ore-body A B did not go to surface, having been first cut by the discovery shaft at 70 ft. down; it is a very short body of ore, almost a chimney, and it diminishes in approaching the lower level; further, the ore-body C D is still less persistent; it is a narrow, short lens which does not hold out to the lower level, nor does it go up more than half-way to surface, but it makes a sort of spurious connection, by means of the raise, with another patch of ore E, on the second level. In practice, such workings as these are largely inaccessible and usually dangerous; as a consequence, the statements of an inaccurate superintendent, who desires to serve his employer by putting things in the most favorable light, are apt to carry more weight than they should, so that, with the usual desire for quick decision on the part of both the vendor and the vendee, the engineer may be pushed to a conclusion which the actual facts do not warrant. It may seem to one who has missed the essential character of these ore-bodies, through the failure to examine the old workings, that the good width of rich ore at H and at M indicates the beginnings of a big body of ore which persists, at least, from one level to the other; but to another man, who has carefully studied the old workings, it is evident that the probabilities point merely to



PLAN
SHOWING SAMPLING
Supposed Ore

FIG. 11



PLAN
SHOWING LODE STRUCTURE
Ore Lenses

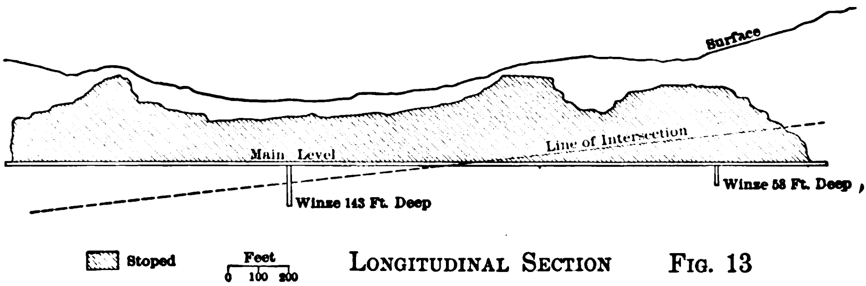
FIG. 12

another narrow lens of uncertain extent. The moral is, don't allow yourself to be hurried into an opinion by either party to the transaction, and beware of workings which are stated to be inaccessible, because such inaccessibility may have a purpose.

Another illustration will emphasize the warning conveyed in the last sentence. In Fig. 11 is represented the single level of a California mine which is reached by the western cross-cut shown to the left of the drawing. The level is 450 ft. long; owing to the fact that the country is a soft black slate the ground is very heavy, and the level is closely timbered throughout, permitting only occasional glimpses of ore, at the points where short cross-cuts have been run out eastward. At these places, D E, F G, B C and H K, the lode is plainly visible, and exhibits from 6 to 8 ft. of fairly uniform quartz carrying an average of from 6 to 7 dwt. of gold, in a district where working costs are about $3 per ton. After sampling these cross-cuts, examining the little there was to be seen, and finding that the ground really seemed heavy enough to justify the close timbering over the level, the engineer came to the conclusion that he was dealing with one of those persistent ore-bodies not uncommon in that part of California, and he estimated the ore to have the continuity exhibited by the cross-hatching in the drawing. However, he had wholly misunderstood the real character of the ore-occurrence, as Fig. 12 will indicate. The close timbering was not necessary in order to sustain the ground alone; it was an excuse for obscuring certain facts. The quartz exposed by the several cross-cuts belonged to a number of small lenses. These abutted against the "fissure," or main line of fracture, which constituted the supposed lode; the lenses were short-lived and lay with their longer axis parallel to the cleavage of the slate; the body at D E only lasted as far as two sets of timber; that of F G died out at 60 ft., and that at B C "petered out" at 40 ft. above the level, while the last one, H K, went up as a narrow body for a distance of 160 ft. Compare Fig. 11 with Fig. 12

and quote Hamlet's comment on his own portrayal of his mother's successive husbands. This incident did not befall a tyro, but an old campaigner who was caught by his own carelessness under circumstances from which only the greatest wariness could have saved him.

Misconceptions concerning the conditions contributory to the localization of ore-shoots and the consequent mistaken ideas as to the future possibilities of a mine have often arisen from a misunderstanding of vein intersections. In the case of a well-known mine in southwestern Colorado a length of 2,700 ft. of ore had been opened up by an upper level. and stopes, which had



LONGITUDINAL SECTION FIG. 13

worked out most of the ore except at one end, and had proved that it persisted to the surface, an average distance of 150 ft. above this upper level. In the meantime two winzes had demonstrated the apparent downward continuance of the ore-body. A longitudinal section of these workings is shown in Fig. 13. In the examination of the mine by several distinguished mining engineers, it was assumed that the winzes, one of which was 58 ft. and the other 143 ft. deep, proved the continuity of the ore-body to an extent sufficient to warrant a price for the property which was a good deal in excess of the net profits to be won from the ground as measured to the bottom of the winzes. In the sequel it was found, after the mine had been purchased, and when deeper workings had explored the lower horizon, that the ore-body owed its existence, and certainly its shape and position, to the intersection with another lode. This made a "scissors crossing," the hinge of which was a line, dipping west at an angle of 7° 30′. The ore-body reached from this line to the surface, while downward it extended about a hundred feet or so. Other scattered smaller bodies of ore were, it is true, encountered, but the main ore-body of the mine, upon which its value was based, extended only about a hundred feet below the broken line shown across the longitudinal section in Fig. 13. Such an instance as this proves the need for deciphering the conditions which have affected the distribution of ore. The crossing referred to was visible in the stopes at the east end, but only to an inquiring observer who suspected some eccentricity of lode structure.

COLLATERAL EVIDENCE.

Of all the collateral evidence likely to aid the engineer in a correct diagnosis of the condition of the mine he is examining, none is so useful as that derived from a study of the surrounding district. Mines situated in the same district are apt, on account of an identical geological environment, to exhibit similar symptoms and to suggest like possibilities. The general study of a region, therefore, is a useful preliminary to the investigation of a particular mine. Moreover, there is, I am glad to say, a certain spirit of *camaraderie* among professional men of the right sort which will enable a stranger to obtain many useful hints from resident engineers, if he is properly made known to them.

The characteristics of ore-deposits within limited areas are often well marked; in one case persistence, without probabilities of either *bonanzas* or *borrascas*, is the rule, as on the Rand; in another case an irregular distribution of values is to be expected, as in most silver-lead deposits in limestone, and also in many rich telluride veins where secondary enrichment has been at work; again, certain lines of faulting and well-defined contacts between sedimentary and eruptive rocks may be recognizable as factors in determining the place of rich bodies of ore, as is illustrated by the Aspen and Rico districts in Colorado.

Another very important factor, in influencing the relative richness of a lode in depth, is the position of the ground-water level. No engineer can afford to disregard it. Two opposite cases may be cited. In certain arid regions of the southwestern part of North America, which it would be invidious to specify further, the persistence of rich ores coincides roughly with the zone of oxidation. I recall a well-known mine which, at the time it was examined by several reputable engineers, exposed an ore-body nearly 1,800 ft. in length. This was the length of the ore traversed by the longest level, which was also the deepest. (See Fig. 14.) Both ends of this level were, however, still in ore. Three winzes proved

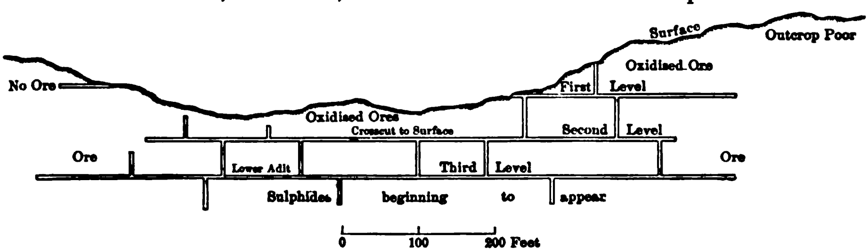


FIG. 14

the ore for a further depth of about 30 ft. The upper workings contained carbonates of lead and iron-stained quartz rich in the precious metals. At the third level there was evidence of the edge of the oxidized zone, for sulphides predominated. All of the winzes left off in sulphides, of average tenor as regards gold and silver, but exhibiting a noteworthy admixture of zinc-blende amid the galena. One engineer who examined the mine allowed 50 ft. below the lowest level as ore to be considered in appraising the value of the property, but he allowed nothing beyond the ends of the level. This was adversely criticized. However, among the reasons prompting a conservative attitude was the recognition of the fact that many gold and silver veins in that region turned into poor zinc-bearing lodes at a short distance below the limit of visible oxidation. In the sequel he was proved to be right. When, later on, the mine underwent extensive development, it was found that at 45 ft. below the lowest level the ore became poor in gold and silver, but heavily charged with zinc-blende, while at the same time the lowest level ran out of the ore-body within a few feet at both ends. In this regard it is a curious fact how often good miners, especially if they are selling a mine, stop their explorations at the proper psychological moment.

The great copper region around Butte, in Montana, exemplifies another aspect of the inquiry. Very extensive exploration, prompted by the extreme richness of the lodes, has permitted of the accumulation of evidence which proves conclusively that the big ore-bodies are the result of a secondary enrichment brought about by the leaching of copper by the ground-water and its precipitation upon the sulphides of the deeper zone. The original vein stone consisted of iron pyrite, copper pyrite and, probably, enargite, while the *bonanzas* consist of the higher sulphides, bornite, covellite and chalcocite. Experiments have been made[1] in the laboratory which illustrate the formation of chalcocite (copper glance) on pyrite by precipitation from a solution containing copper sulphate, such as would be the product of oxidation through the agency of the ground-water. As a result of such reactions the outcrops are poor in copper and silver, because these have been leached out; the silver appears at a comparatively shallow depth (three or four hundred feet below the surface) so as to form a zone of maximum enrichment in that metal, while the copper has been deposited deeper still, so as to form the magnificent masses of high-percentage ores which have made Butte so productive. Below these come the first-formed ores, chiefly pyrite with a little copper pyrite, without the higher copper sulphides which have enriched the overlying zone. While, therefore, the lower limit of the horizon of secondary enrichment has been passed through in some of the mines, it must be added

[1] "The Synthesis of Chalcocite," by H. V. Winchell. ENGINEERING AND MINING JOURNAL, May 23, 1903.

that in others the rich sulphides extend to a depth of over 2,000 ft. from the surface, so that the effects of the ground-water circulation continue to a profundity quite exceptional in the experience of mining. This may be due to the intensity of the fracturing which followed the deposition of the earlier sulphides, and it may be partly a result from the open character of the lode channels which has permitted of the far-reaching penetration of the ground-water, but, whatever the cause, it renders the problem of ore-occurrence at Butte quite exceptional, particularly when compared to cases such as the one quoted in the preceding instance, in Fig. 14. A novice who has sampled the shallow workings of a young mine in a region such as Butte would be likely to be misled by the low percentage of copper, and therefore enunciate an unfavorable opinion, whereas one who recognized the effects of ground-water leaching and was guided possibly by a knowledge of the changes encountered at greater depth, in a neighboring mine, would make quite a different inference. Under other circumstances in another region the occurrence of the higher sulphides, such as covellite and chalcocite, would suggest secondary enrichment and warn the engineer against counting upon a persistence of conditions which are frequently quite local.

Considerations such as these suggest very forcibly that keen observation and wide experience are required for the appraisement of the potentialities of a prospect.

CONCLUSION.

This discussion of the subject has emphasized one great factor in work of this kind, and that is—*the personal equation.* No two men set to work in exactly the same way, and no two men make exactly the same deductions from a complicated series of data. My views on the subject are those based upon my own experience—hence the inevitable limitations of my presentation of it. For this reason, also, I have omitted to refer to the literature which deals with sampling and estimates of ore, because it would have extended this contribution to uncomfortable length, had I taken up the other aspects of the inquiry as discussed by other men. Herein lies my excuse and apology to the Institution of Mining and Metallurgy, to Messrs. J. D. Kendall, E. B. Kirby, A. G. Charleton, W. Wybergh, G. A. Denny, S. J. Truscott, D. W. Brunton, W. McDermott and other authoritative writers on the same subject.

The conclusion of the whole matter is sufficiently obvious—so obvious as to need but little further insistence. If the discussion of the methods to be applied in the sampling and estimation of ore has served to accentuate the difficulties to be encountered in the diagnosis of a mine, then it will have fulfilled one of the purposes of this contribution. *"Chi va piano, va sano."* Extreme care is necessary at every stage of the work—care and experience, the experience born of wide knowledge and practical work, without which a man in a mine is no better than the proverbial bull in a china shop, with a strong suggestion of a coming smash!

The old hands—the engineers who have sampled mines from China to Peru—do not need my maxims to guide them. They have lost the cheerful confidence of their apprentice days and are saturated with the experience of difficulty and doubt which have been frankly faced on a hundred occasions. To the youngster, who still has to receive his first fall and to realize that few data are absolutely certain, also that data carelessly obtained are inevitably uncertain—to him this analysis of methods of work will, it is earnestly hoped, serve as a red flag of warning. To the general reader who is usually more in sympathy with the pains of the unfortunate investor in mines than he is with the causes which may vitiate good advice from the expert, to him these *obiter dicta* will, I trust, suggest forcibly that good advice is hard to get and expensive—yet cheap indeed compared to the costly experience of entrusting onerous professional duties to the inefficient.

"ORE DEVELOPED," A DEFINITION.*

BY PHILIP ARGALL.

The phrase "Ore in Sight," so commonly used as an alleged measure of value in mine reports, is, in my opinion, a very poor expression. Taken literally, as the non-professional man is most likely to understand it, one cannot defend its use except as a misleading, if not deceptive, euphony.

The only "ore in sight" in or about a mining property is that broken and displayed at surface in the ore-bins, or in dumps. Perhaps I should also include ore broken or visible in the underground workings; but this is not what is usually meant by "ore in sight" in mine reports.

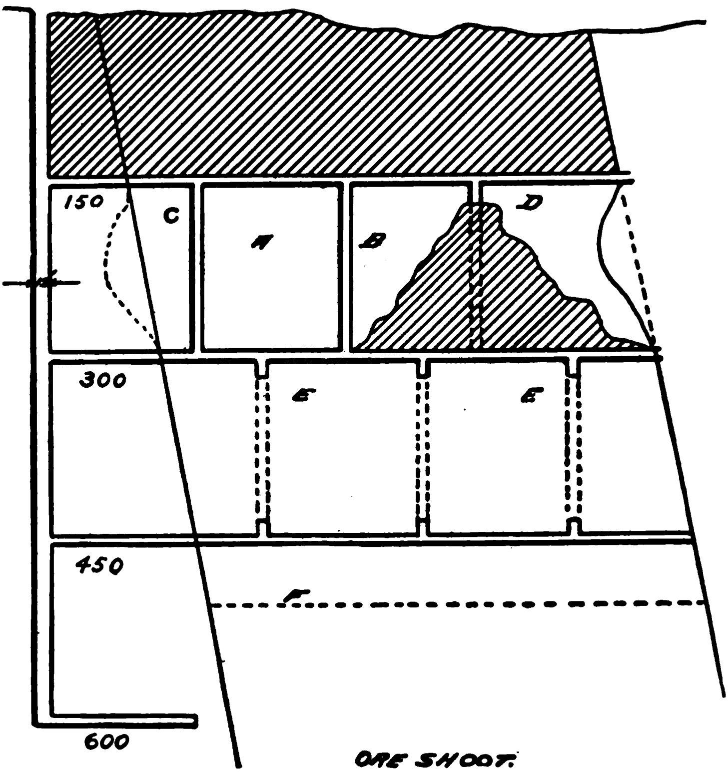
I believe the majority of mining engineers call vein-matter blocked out and accessible for measuring and sampling on all four sides, or at the very least on three sides, as "ore in sight," while strictly speaking it is only the four planes bounding the block that are visible to the physical eye. The "mind's eye" should have no place in such an estimate.

I take it that the whole purpose of sinking shafts and winzes, running cross-cuts, levels and raises, is, first, to open up and develop ore; and, secondly, to provide ready means to extract and market this ore when developed. Once a given piece of vein-matter is blocked out by, say, two drifts, 150 ft. apart, and two winzes, 200 ft. apart, it has reached its highest state of development, that is, it is ready for removal by stoping; and it is also in the best form for sampling and measurement, in order to obtain a close estimate of its commercial value. I would submit, then, that such a block had best be called "ore de-

* From THE ENGINEERING AND MINING JOURNAL of February 14, 1903.

veloped" and not "ore in sight." The former phrase would correctly describe what it is, while the latter just as clearly shows what it is not.

"Ore developed" should in every case be accessible for measurement, sampling and full examination on all



sides.[1] Block A, on the diagram attached, showing four exposed sides, is perhaps the more usual form met with in a developed mine. Block B, however, with three exposed sides, also comes under our classification of "ore

[1]The planes called foot and hanging walls are not considered as sides.

developed," as would also any irregularly shaped ore-body visible and fully accessible, on and along all portions of its perimeter.

Inasmuch as "ore developed" forms the subject of the highest possible, or most accurate, estimate engineers can make of ore in place, it should be hedged in with the invariable and unalterable requirement, exposed on all sides up to the full thickness of the ore. Under this condition the estimates of independent examining engineers should agree within the limits of experimental error. As a general rule, one is safe in stating that the smaller the blocks of "developed ore" the more accurately can their contents be estimated. These blocks, then, should be of moderate dimensions. In ordinary vein mining the levels are usually placed at intervals of 100 to 150 ft. apart, as measured along the dip of the vein. I would suggest as a safe rule, within these limits, that the length of such blocks of "ore developed" should not exceed twice their depth.

It may be suggested that it is not always imperative to completely block out ore-ground before stoping. Quite true. The parties, however, who are developing their mines for the purpose of selling them, would be well advised to do so. Otherwise the ore partially blocked out, and in various minor stages of development, must receive separate and lower classifications.

For blocks of partially developed vein-material, hidden on one or more sides, I would suggest the phrase "ore being developed," or, for shortness, "ore developing." Two levels, say, 150 ft. apart, simultaneously penetrating an ore-shoot, are, as they advance, daily increasing the amount of "ore being developed," which, on further opening up by winzes or raises connecting these levels and cutting the ground into blocks, becomes "ore developed."

"Ore being developed" naturally falls into three classes: First, where one side only is hidden; second, where two sides are hidden; third, where three sides are hidden.

As an example of the first class, we will take block C, which on a casual glance might appear just as safe an estimate as block B. On closer examination, however, it will be noticed that on the hidden side we can neither determine the assay value of the ore, its thickness, nor its actual termination. For example, if the shoot follows the heavy line, as one naturally assumes it would, we have data for a certain tonnage, while if it follows the dotted line, we have an increased tonnage. Similar remarks apply to block D, showing how the assumed tonnage might be decreased.

It is therefore abundantly clear that a given block of ground having one hidden side cannot be estimated as closely as one having all sides exposed, inasmuch as in the former about 25 per cent of the necessary data is unobtainable. We are therefore fully justified in excluding the block having one side hidden from an estimate of "ore developed," or, if you please, "ore in sight."

Again referring to the diagram, block E, with two sides hidden, cannot in the very nature of things be estimated as closely as blocks C and D, hence we class it "ore developing," second class, while block F, with three sides hidden, very naturally falls into the third class estimate of "ore being developed."

We next come to the future value of the ore-shoot. In other words, to what depth will the pay-ore extend? We assume the ore-shoot is of fairly uniform dimensions and value; that it continued so to the lowest point of exploration, the 450-ft. level on our diagram. The experience in the district went to show that the horizon of pay-ore extended to 1,000 ft. In this case the ore is not even in a stage of "ore developing"; it may be entirely invisible, yet one has reasonable assurance from the appearance of the vein and ore-shoot, from the experience obtained in adjoining properties, and from other physical phenomena, that pay-ore exists in this shoot to a depth of at least 900 ft.; consequently the engineer, after making such allowances as he deems safe, looks forward with confidence and reasonable assurance that the shoot of pay-ore will extend to some considerable depth, perhaps to 1,000 ft. This I class as "ore expectant." It deals rather with the future than with the present, and more in the region of the imagination than of fact, but is, nevertheless, an important factor in every mine valuation, dealing as it does with the probable life of the property as a producing mine.

"Ore expectant" is perhaps the most difficult estimate, if estimate it can be called, that engineers are compelled to make, because of the few facts available; hence it is only to be supposed that opinions and estimates of different engineers must widely vary. While, therefore, with "ore developed" the highest and most accurate estimate of ore in place can be made, "ore expectant," in the same sense, forms the lowest and least accurate. Very few, if any, mine owners would sell a property for the net value of the "developed" and "developing ore," unless they had good reason to believe the mine to be practically bottomed; hence the necessity of having a phrase to cover such estimates, as well as uniform and thoroughly recognized rules to govern their compilation.

These three phrases, "ore developed," "ore being developed" and "ore expectant" should cover, in metalliferous mines, all estimates a mining engineer is called upon to make. I now put them forward for the consideration of the profession, not as the best possible names and classifications, but as sound, useful and definite phrases to govern ordinary estimates of mine valuation. They will cover any condition I have met with in a practice extending over 25 years in this and other countries; and they have not only proved useful in my work, but are also the best phrases I can evolve to correctly designate clear and concise estimates.

Every report on a mining property should give the cost of stores, the mining and milling cost, and the gross and net values of the ores; therefore it should not be a necessary requirement to have "ore developed" always pay-ore. The gross and net values at the time the examination is made will fully govern the then value, while at later dates the improvements in mining and milling can usually be depended on to increase the net value, often to the extent of showing good profits, in the course of a few years, on formerly practically valueless ores. The gross value is, when reported in ounces and percentages of metals, always a fixed point of departure, from which the net value can at all future times be deduced when the price of the metals and cost of treatment are taken into consideration.

It may be the ambiguous phrase "ore in sight" is so deeply rooted in the minds of mining operators, promoters and investors, that it cannot well be replaced by a better one. I hope this is not so; nevertheless, should these notes provoke a sound discussion of the whole subject, preparing the way for definite classifications of ore estimates, with clear and concise rules governing each class, I shall feel that my efforts have been to some purpose.

In conclusion, permit me to state that the various methods of mine sampling, and the possible errors in estimating tonnage and value, are excluded from the scope of this letter. I simply desire to present for the consideration of mining engineers the classifications above outlined, and which I summarize as:

Ore Developed.—Absolutely and without variation, ore exposed on all sides.

Ore Being Developed.—First class, blocks with one side hidden; second class, blocks with two sides hidden; third class, blocks with three sides hidden.

Ore Expectant.—The prospective value of a mine beyond or below the last visible ore, based on the fullest possible data (clearly set forth) from the mine being examined, and from the characteristics of the mining district.

COST PER TON AS A BASIS OF MINE VALUATION.*

By R. Gilman Brown.

Hardly second in importance to the determination of value per ton, by careful and systematic sampling, is the determination of cost per ton from the mine accounts. The object of sampling has been attained when the gross valuable contents of the ore exposed in the mine have been determined. This, for the sake of convenience in subsequent calculation, is usually reduced to value per ton. From this gross value per ton must be deducted the total cost per ton and the loss per ton in treatment, the remainder being the net value per ton. Obviously an error in cost per ton is just as important as an error in gross value per ton, so that it is necessary to examine with as careful scrutiny the method of obtaining the one as of the other. Several pitfalls have been pointed out recently in the columns of this Journal which will be ignored in this present article; or, rather, will be assumed to have been satisfactorily avoided, the desire being not to obscure another factor in valuation which has been touched upon but lightly, if at all.

It is not intended in the present article to go into the details of mine accounting, but it will be assumed that in some way or other the engineer has obtained certain segregated totals representing the expenditure during a definite period in the various operations connected with mining and beneficiating the ore, and that the sum total of these segregated accounts represents the total cost of operations for the period in question.

It is usual to divide these segregated totals by the tons

*From The Engineering and Mining Journal of August 29, 1903.

of ore treated during the same period, and to call the quotients the cost per ton for the various departments. In a certain sense the sum of these is *a* cost per ton, though not properly to be considered *the* cost per ton, as the result is rather a hazy approximation representing, perhaps, average work for the mine, but not sufficiently definite to be used with confidence in the delicate work of valuing ore reserves.

Let us assume certain natural divisions of the accounts into stoping, development, reduction and general expenses. All the segregations can be easily grouped under these headings; and this would naturally be done in the process of arriving at the cost, in the manner to be described. In the inexact method commonly employed, these totals would all be divided by the same tonnage—probably by the tonnage reported from the mill or reduction works, whereas, this would only give true results for the last two items, namely, reduction and general expense. For stoping, the result might be approximate except in the case of a mine carrying a considerable amount of ore in the stopes. For development, it could only give the true value when the same amount of ore was stoped as was developed during the period. If development fell behind, the result per ton would be too little; if it exceeded the output, it would be too much.

This is the general statement of the matter, but it can be made clearer by considering a concrete case. It is proper to say that this, though based on practice, has been elaborated, with the assumption of certain values, to suit more general conditions.

The period is 12 months.

Tons treated, 50,000.

Total return per ton, $5.26.

Total loss per ton, 64c.

Total gross value per ton in ore, $5.90.

Below is given in tabulated form the costs of the various departments and the costs per ton, as commonly calculated:

	Total.	Per ton on basis of tons treated.
Stoping	$58,000	$1.16
Development	50,000	1.00
Reduction	92,000	1.84
General expenses	22,000	.44
Total	$222,000	$4.44

The following tonnages are also given:

	Tons.
Ore broken in the stopes	10,000
Ore standing, blocked out, ready for breaking	100,000
Ore reasonably expected, but partly, if at all, developed	50,000
Total	160,000

These are the quantities assumed to be found by the engineer on his investigation of the property, and the recoverable value per ton will be taken at the average of the past year, which we will assume to have been determined to be the fact by careful sampling. The most natural way of calculating the value of these reserves would be as follows:

Total recoverable value of 160,000 tons, at $5.26	$841,600
Costs on 160,000 tons, at $4.44	710,400
Apparent profit in reserves	$131,200

This is manifestly incorrect. Stoping and development should not be charged against ore already broken, nor should development be charged to that standing blocked out and ready for stoping. The estimate should read as follows, assuming the figures for cost per ton to be correct:

10,000 tons broken in stopes, at $2.28 per ton for milling and general expense	$22,800
100,000 tons developed, ready for stoping, at $3.44 ($2.28 + $1.16)	344,000
50,000 tons, reasonably expected, but not developed, at $4.44	222,000
Total costs	$588,800
160,000 tons, recoverable value as above	841,600
Net profits	252,800

The cause of the great difference is obvious. It should be noted that in the accounts, transportation and handling costs are assumed to belong in general expenses. The above figures must be taken as thrown in, apart from the fundamental matter with which this article opened and they contain errors, as was indicated in our opening lines.

Reduction costs and general expense are properly reduced to the per ton basis by dividing by 50,000 tons, but stoping and development cannot properly be so reduced until we know whether 50,000 properly represents the tons stoped and the tons developed. In what follows we are using some quantities that an engineer examining the property can scarcely have come at directly, and indeed he will be fortunate if he has them at all; but, recognizing their importance, by inquiry and estimate, he must arrive at some sort of a probable value for them.

We have, as a general proposition, that the actual amount of ore broken during the year is equal to the ore on hand broken at the end of the year, plus the ore treated during the year, and minus the ore on hand broken at the beginning of the year. In the same way the ore developed during the year is equal to the ore blocked out at the end of the year, plus the tons of ore broken during the year, and minus the ore standing blocked out at the beginning of the year. Applying this to our concrete case, we will assume the following values for tonnage at the beginning of the year:

	Tons.
Broken in the stopes	20,000
Standing blocked out	120,000
Reasonably expected	60,000

Ten thousand tons plus 50,000 minus 20,000, equals 40,000; which turns out to be the actual ore stoped during the year, so that the true cost of stoping per ton is 58,000 divided by 40,000, equals $1.45 per ton. In the same way 100,000 plus 40,000 minus 120,000, equals 20,000 tons, the actual ore developed during the year; and $50,000, the total spent on development, divided by 20,000 tons, equals $2.50 per ton, the true cost of developing a ton of ore. Inasmuch as no costs are credited in this discussion to the ore reasonably expected, we need not carry this further, though the same reasoning would hold in regard to it. Collecting our true cost per ton we have:

Stoping	$1.45
Development	2.50
Reduction	1.84
General expenses	.44
Giving the true total cost per ton at	$6.23

This shows that the ore at this mine will not actually pay expenses for handling unless greater economies can be practiced; whereas, our first calculation gave a profit per ton of about 80 cents. To a certain extent, then, the matter concerns the mine manager as well as the examining engineer, though it is in the interest of the latter in particular that this article was prepared.

Proceeding next with the valuation of ore reserves, we reproduce our earlier figures with the corrected costs introduced:

10,000 tons, broken, at $2.28 per ton	$22,800
100,000 tons, developed, ready for breaking, at $3.73 ($2.28 + $1.45) per ton	373,000
50,000 tons ore, reasonably expected, at $6.23	311,500
Total	$707,300
Recoverable value, as above	841,600
Net value on the reserves	134,300

In order to lay the whole matter more clearly open and even at the risk of being tedious, it is worth our while to make another assumption regarding tonnages at the beginning of the period, as below:

	Tons.
Broken in the stopes	None.
Standing ready for breaking	80,000

The tonnage and cost per ton follow in summary:

	Tonnage for year.	Cost per ton.
Stoping	60,000	97c.
Development	80,000	62c.
Reduction and general expense, as before	50,000	$2.28
Total		$3.87

On this basis, the value of the ore reserves is:

10,000 tons, broken in stopes, as before	$22,800
100,000 tons, ready for stoping, at $3.25 ($2.28 + 97c.) per ton	325,000
50,000 tons ore, reasonably to be expected, at $3.87	193,500
Total charges	$541,300
The gross recoverable value, as before	841,600
Profit in reserves	300,300

The differences shown clinch the statement with which this paper opened.

As a summary of the above there are two general principles to be enunciated:

(A). Cost per ton is the quotient of total cost divided by the actual tonnage resulting from that expenditure.

(B). Net value per ton is the gross recoverable value per ton, less cost per ton for those natural divisions of the work still to be performed upon the different classes of ore.

Although the above principles are fundamental, like all general statements, they may easily be pressed to extremes, and it is for the engineer, after analysis of the situation, to decide the particular extent of their application; a failure to recognize them at all, on the other hand, may invalidate the conclusions drawn from otherwise reliable work.

MINE VALUATION.*

BY J. PARKE CHANNING.

May it not be possible to have a mine with too much "ore in sight"? I ask this question because the general tenor of the discussion on mine valuation has made "ore in sight" the crucial test of the value of a property.

If based on this test, many of our good iron mines would make a sorry showing; and yet their capacity for production is well known, and year after year they come up to expectation. If one has a fairly regular deposit, is anything to be gained by rushing the openings so that 10 or 20 years' supply of ore is opened up? Will not the interest charges on the cost of this development, the expense of re-timbering the openings and the pumping charges be a heavy drain on the income?

In Butte, to-day, litigation has forced development to such excess that it is estimated that certain drifts will have to be re-timbered four times before the ore is stoped. Several of the prominent Lake Superior copper mines have ground opened up many years in advance with but questionable benefit, as the drifts driven every 100 ft. do not show the full width of the lode and the rock from these openings has not been stamped by itself, so as to show its yield. Cutting out stopes every 300 ft. would at least have been cheaper and have given more idea of the yield to be expected.

The president of a prominent western railway boasted that he had just added to the company's coal-land holdings a 90 years' supply. A little figuring showed him that the interest on his investment would make his coal 90 years hence pretty expensive.

A few years ago Prof. Robert Peele, Dr. John H. Banks and myself were required to place a valuation on four

*From THE ENGINEERING AND MINING JOURNAL of September 12, 1903.

pyrite mines for a proposed consolidation. They were in various stages of development, and one of them had more ore in sight than the combined tonnage of the other three. This large tonnage left in the mine consisted of ore which in the earlier days would have produced fines then of little value. At the time of the examination the development of mechanical roasting furnaces had placed fines on a par with lump, and this ore was now available for extraction. The question arose, What value was to be given to this ore in sight? I quote from our report:

"We have taken the ground that in mines of this character the deposits are so regular that the better test of their relative values is to be found in their capacity for production per 100 ft. of depth, rather than in the number of tons of ore available for immediate shipment; that is, 'in sight.' Taking, as we do, this view, we desire to minimize the effect produced on the value of each mine by the varying amounts of ore in sight, believing, for example, that by sinking B mine and C mine each about 200 ft., and running the necessary drifts, we would have in each of these mines an amount of ore in sight equal to that at A mine. This result would be accomplished by the expenditure of a comparatively small amount of money in each case, which would be charged to development."

Following this line of reasoning, and attempting perhaps the rather difficult task of "giving mathematical exactness to phenomena governed by the complex laws of nature," we evolved the following formula:

$V = 5\,ax + by + c$, in which—

V = Value of the mine.

a = Net profit per ton of ore mined.

x = Annual estimated output in tons.

b = Cost of development per ton of ore opened up.

y = Tonnage of ore in sight above the bottom level.

c = Value of the equipment and stocks on hand.

In the above formula it will be seen that the practical valuation of the mine was assumed at five times the annual profit. The figures substituted in the above formula for the four mines were as follows:

	a	x Tons.	b	y Tons.	c	V
A.........	$0.84	96,500	$0.062	293,000	$97,100	$520,566
B.........	0.94	120,500	0.058	88,800	115,400	686,900
C.........	1.15	79,500	0.100	117,200	67,650	536,495
D.........	0.91	15,000	0.150	63,000	35,100	112,800

Some three years later I had almost the same problem in a group of copper-silver-gold properties in a western State which it was proposed to consolidate, as the various ores, with the addition of a little limestone, would make a most economical smelting mixture. In this problem the copper mines E and H were well opened up, while the two silicious gold and silver mines F and G had not the openings and development that proper mining would demand. The bottoms looked fairly well and the past records were good, but no such assurance of "future performance" was to be counted on as in the regular pyrite mines previously described.

From the data available the following figures were compiled:

	$ay + c$	ax	Owner's price.
E..................	$800,000	$284,375	$6,000,000
F..................	128,000	112,000	250,000
G..................	866,000	630,000	3,200,000
H..................	600,000	175,000	750,000
	$2,394,000	$1,201,375	$10,200,000

In the above $ay + c$ represented the profit in sight, the tonnage in sight y being multiplied by the estimated profit per ton a, instead of by b, as in the pyrite mines.

The figures ax were only tentative in this case, and would have to be used as a guide only.

The scheme of consolidation was never carried out on account of the high valuation placed upon their properties by the owners of E and G. The owners of E wanted 60 per cent of the consolidated stock, while they had but 33 per cent of the total value in sight and were capable of contributing only 25 per cent of the earnings. The owners of G were not unreasonable in their demands, were it not for the fact that their future was doubtful and with only a little over one year's ore in sight they were demanding a five years' purchase.

Had the decision been in my hands I would have consolidated on the following basis: E, $2,000,000; F, $250,-000; G, $2,000,000; H, $750,000; total, $5,000,000.

I give these two cases, the first showing the extreme limit in which "profit in sight" is almost negligible. The other limit in which "profit in sight" is a *sine qua non* has been gone into most thoroughly by your previous contributors. My second case is a mean between the two; and in estimating the value of a property either as an arbiter or for a purchaser the engineer must integrate his equation between the two limits. Buying a mine on the basis of "profit in sight" is much like dealing in pork or dry goods, and needs not the services of a trained engineer as much as it does careful, plodding samplers and assayers.

What I wish to bring home to the engineer examining properties for an investor is the point that his client's greater profits are not to be made from the purchase of those properties where the "profit in sight" is so great, but from those which the engineer's judgment tells him will improve with development. As the late Marcus Daly said to one of his men who had spent two years in fruitless search for a mine, "Why the devil don't you get reckless once in a while and spend forty or fifty thousand dollars?"

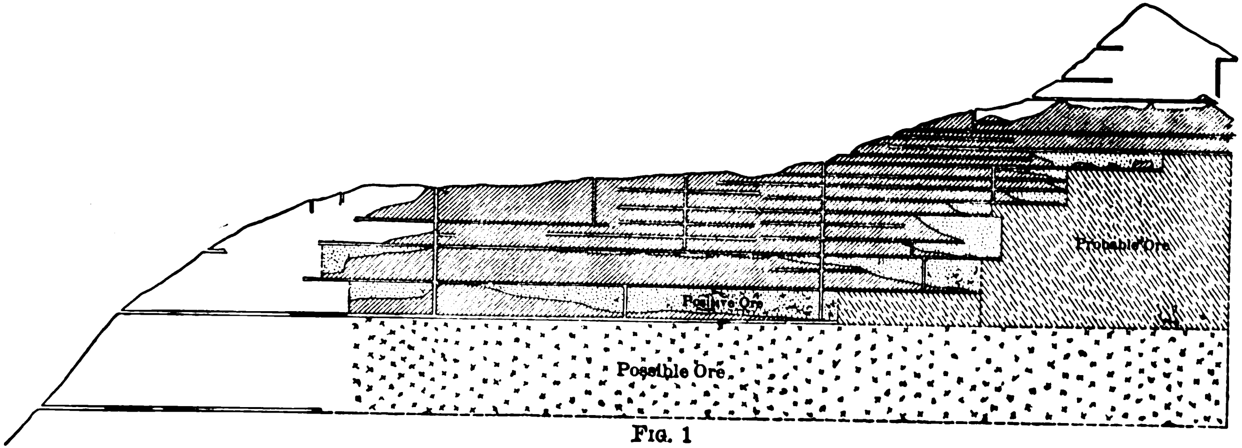


FIG. 1

"Positive Ore," Ore-ground proved on 3 sides
"Probable Ore," " " " 2 "
"Possible Ore" " " " 1 "
Ore-ground stoped out
1 inch - ft.

DISCUSSION.

ORE DEVELOPED.

The Editor:

Sir.—It is with some diffidence that I venture to question the advantage of Mr. Philip Argall's proposed classification of ore-tonnage estimates as used in mine reports. I am, of course, ready to agree that "ore in sight" is always an unwise and, frequently, a misleading expression, as applied to ore-ground in place; the phrase is sufficiently discredited by this time for its use to be discontinued by general consent.

But may not any other definition prove misleading to a less extent? Take, for instance, Mr. Argall's "ore developed"—meaning, in all cases, "ore exposed on all sides." Most of us have known, many of us have experienced, cases where blocks of ore so exposed on four sides have been found to enclose a large barren patch in the center. However rigid a rule we may adopt, we cannot arrive at certainty.

The amount of weight to be attached to exposure on four sides, on three, on two, or one one only, varies with the conditions of each particular case. Fig. 1, for instance, shows a section of vein-workings from which, with other data, estimates were made by my brother, the late Arthur L. Collins, under the three headings of "positive ore," "probable ore," and "possible ore." Who, after examining the section, and bearing in mind the phenomenal lateral extension of the ore-body shown, can doubt that far more reliance can be placed on blocks marked in the section as "positive ore," even though some of them are exposed on three sides only, than on many blocks opened up on four sides in veins where the ore-bodies are of the bunchy and erratic type which we must recognize to be, after all, by far the most frequently encountered? Even the "possible ore" of Fig. 1—ground where the ore is proved to exist on one side only—can be depended on to a far greater extent than usual.

My contention is that the amount of evidence to be required when making estimates of ore-tonnage, and the number and nature of classes into which estimates should be divided, must depend on our general conclusions as to the nature and permanence of the ore-bodies in the mines under consideration, the distance between the workings, etc. I do not think that any rules can be made which will lessen the necessity for dependence on the examining engineer's individual judgment; and I distrust all cast-iron classifications, which do not allow for the infinite complexity of natural conditions. The only useful general rule is that no estimate of tonnage should be made unless accompanied by sketches indicating the basis on which it rests.

I understand Mr. Argall to suggest that, as it is frequently not advisable in the ordinary course of mining to block out ore so as to come under his definition of "ore developed," parties desirous of selling should go to the additional expense of doing so. While, however, I admit that the valuation of mines for sale-purchase is a very important duty of the mining engineer, I cannot see that methods of mining should be modified to suit it. A mine primarily exists for the purpose of being worked to the greatest economical advantage, and an engineer must expect to make his estimates conform to the particular case. There are many instances where the additional openings which would become necessary to bring proved ore-ground within the limits of Mr. Argall's definition of "ore developed" would increase the cost of exploitation to such a figure that the profit-margin would be seriously curtailed.

Take, for instance, the ore-body shown in Fig. 2—a case which is typical of perhaps the largest number of ore-bodies in fissure-veins. Such ore-bodies are usually most economically developed by a single raise through the ore, as shown. According to Mr. Argall's classification there is no "ore developed." Yet, certainly the ore is there, more or less; it is certainly developed, so far as it is economically required to be. I have indicated by shading the basis which I should have taken for the purpose of making an estimate of ore developed. Such ore is by no means certain, nor is any other; but I should use such words in referring to it as would clearly signify with what degree of confidence I regarded it. Actual

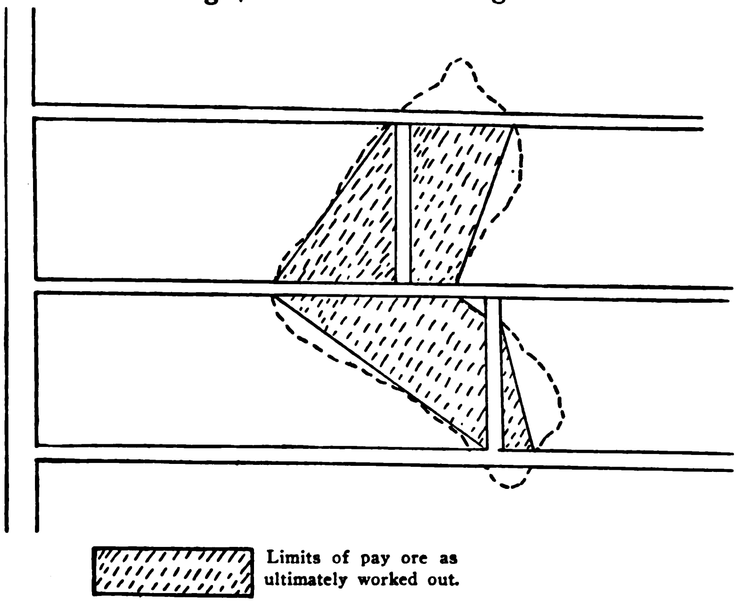


FIG 2.

ORE DEVELOPED, AS ESTIMATED FROM WORKINGS SHOWN.

certainties as to ore are reached only after it has been crushed and sampled; and I might almost add, paid for.

It would be a mistake to sacrifice the two essentials, clearness and accuracy, for the sake of getting concise and well-sounding phrases; and equally so to attempt to classify all possible estimates of ore under prejudged headings. Nature does not always plan ore-occurrences to suit our systems of classification.

While it hardly comes within the limits of the same discussion, I would say a word in favor of the prospecting pick for purposes of mine sampling, notwithstanding the authority of Mr. T. A. Rickard. I have found that by the alternate use of the pick and hammer ends, very fair samples can be taken in all but exceptionally tight ground, where the single jack and moil become necessary. It has the additional advantage that an engineer can take his samples personally, and that the time and labor of sampling are greatly lessened; points of which Mr. Rickard would be the first to admit the significance. It certainly, however, requires more individual judgment on the part of the sampler.

I remember a case where I took a large number of samples alone, some time after sampling by a very prominent firm, the evidence afforded by their grooves still standing to show that the work was properly done. In this case the subsequent working of the mine proved that my average was more reliable; by no means because it was done in a more honest or painstaking manner.

GEORGE E. COLLINS.

Denver, Colo., Feb. 24, 1903.

The Editor:

Sir.—The letter of Mr. George E. Collins, in the issue of the JOURNAL for March 14, 1903, continuing the discussion in regard to sampling and estimates of ore, induces me to offer a few suggestions along the same line of criticism. Mr. Collins says: "The amount of weight to be attached to exposure on four sides, on three, on two, or on one only, varies with the conditions of each particular case." And further on, "And I distrust all cast-iron classifications, which do not allow for the infinite complexity of natural conditions."

However much ability the man to whom the examination of a mine is entrusted may have to sample the available ore geometrically blocked out, he is unworthy the confidence reposed in him if he is unfamiliar with, or neglects to take cognizance of, the principles which govern the deposition of ores. A knowledge of these geological principles implies not only mineralogical training, and a knowledge of the broad general rules by which ore-deposits, through the accumulation of experience, have been classified, but it includes a consideration of the nature of the enclosing and adjacent rocks, and, what is more important, a recognition of the phenomena of ore-shoots.

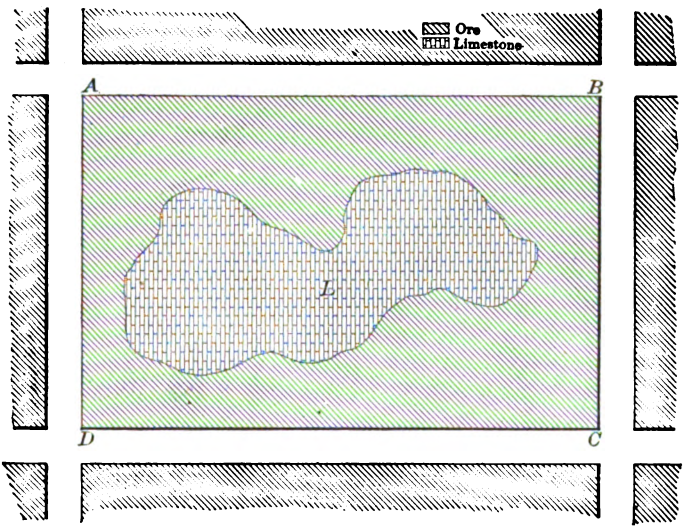
The much-abused term, ore-shoot, or shoot of ore, as applied to mineral veins, may be defined as that portion of a metalliferous deposit within whose boundaries the mineral mass is commercially valuable. This definition purposely omits specifying the shape of an ore-shoot, and any reference to the reasons for its existence. It is evident that the form and size of the ore-shoots in a given mine must depend, not on any scientific law, but, for the most part, upon the actual working expenses. In a mine which has been worked for a period of years, the worked-out portions of the vein usually afford, by their form and dimensions, a fairly reliable index of the size and shape of the ore-shoots for that mine, but for that mine alone.

The mining engineer who examines and reports on a mine in which the ore-shoots have thus been defined by local experience may commit an act of injustice to the intending purchasers, to the vendors and to himself, if he neglects to moderate his calculations, based upon the actual sampling of ore blocked out, by a proper consideration of the system of ore-shoots as developed by previous workings.

In a mine whose workings are on a fissure-vein, experience has shown that the ore-shoots lying in the plane of the vein have frequently a considerable amount of regularity, as regards size and distribution. This is especially the case in veins whose principal gangue is quartz, and whose values consist of any or all of the minerals, gold, silver, lead and copper. The engineer should consider it a part of his duty to ascertain if the characteristics of the ore-shoots in the vein he is examining are peculiar to that particular mine, or are duplicated in other mines of the same district. The gathering of such data is frequently rendered impossible by local jealousy or other motives. The data are usually obtainable, however, and sometimes detailed published maps of the district in question exist. In most large mining districts of the world, both surface and underground data have been published and are available for those who care to use them. If the vein under examination is one of a series, upon which operations in different mines have been conducted for a long period, and which have been shown to present a uniformity or similarity of conditions, the engineer has a largely increased supply of material at hand from which he may draw conclusions.

To take another example of ore-deposits, if the mine in question is operated on a silver-lead bedded limestone deposit, of the kind sometimes referred to as a "contact," the form of one ore-shoot may afford no clue as to the form of the next one to be encountered. From the very origin of such a deposit, it may generally be assumed that the occurrence of the ore will be subject to less definite laws than is the case in fissure-veins. It is occasionally found, however, that a definite local disposition of the ore in shoots in a bedded silver-lead or zinc deposit occurs. The engineer, in examining a mine in which such an occurrence has been proved by the work already done, will naturally be at fault if he takes no account of the history of the property and its previous underground development. He will, however, be likely to exercise unusual caution in estimating the three classes of "positive," "probable" and "possible" ore, when dealing with a class of deposits which are genetically connected with the chemically induced replacement of limestone by metallic sulphides.

In the accompanying diagram (plan) the ore-body represented is an occurrence in a limestone bed, say, 7 ft. thick. The bed, itself lying flat, is heavily mineralized. The carbonate of lime has been replaced by metallic sulphides carrying values. The enclosing beds, namely, those lying above and below, are barren, and the mineralized bed itself contains barren patches, sporadically distributed. Assume that the ore-body thus defined, a portion of which is here represented, had dimensions as follows: Seven feet thick, that is the thickness of the limestone stratum, 150 ft. long and 90 ft. wide. The



Plan of a Part of the Workings of a Silver-Lead Mine in Horizontally Bedded Limestone.

four tunnels represented are all run in this ore-body, and by their intersections enclose a portion of it, A B C D. In other words, a block of ore is exposed on four sides, 7 ft. thick, 45 ft. wide, and 70 ft. long. If one should apply an arbitrary rule of sampling in the examination of the mine in which this case occurs, the ore in question must be classed under the head of "positive." While not questioning the correctness of his classification, I have endeavored to show, by the diagram, the error to which the examiner would be liable, should he estimate the block represented by A B C D as ore. On the other hand, if the examiner takes into consideration the geological principles on which the class of limestone silver-lead deposits depends, he will probably allow in his calculations for the possibility of the presence of the patch or horse of barren limestone L. At any rate, he will be most assiduous in his efforts to find out if patches of normal limestone, unaffected by the ore-bearing solutions, have been encountered in previous workings of the mine, or in the surrounding mines of similar character.

The term ore-shoot may be said to be a development of the experience of that invaluable member of the mining profession, the mine foreman. His every-day contact with the ore, and with the profit and loss conditions of handling it, makes him keen to recognize its slightest variations, so far as can be judged from its appearance. The very fact, however, that the term "shoot of ore" has primarily a commercial and not a scientific definition, has resulted in an exceedingly loose application of it. Would it not be an advisable point for discussion as to whether the word "shoot" should not be more closely limited in its uses?

A fissure may be primarily of varying width, especially when the enclosing walls are slates or metamorphic schists, and the vein is conformable in strike with their schistosity. The vein-filling, or ore, with which the fissure has been filled, may, when drifted on, present at one station a width of 6 ins., and at another, perhaps 100 ft. farther along, of 6 ft. Assume that the ore carries 0.5 oz. in gold. There may be a recurrence of the wide and narrow portions of the fissure, giving a succession of lenses of ore. Naturally the drift must be carried wide enough for the operations as long as the vein is followed. The vein will be stoped only in those portions where the vein-filling widens to such an extent as to warrant its being extracted and milled, or, in other words, where it may be defined as pay-ore. In those parts of the vein where the vein material occupies only 6 ins., or possibly even a narrower space, no more ground will be broken than necessary, and the foreman will define the intervening narrow space along the drift, between any two lenses of ore, as barren ground. His "shoot" will be limited in its length along the drift by the imaginary planes between which the two walls of the lenticular opening in the vein contain sufficient ore to be profitably extracted. All inside the wide part of the vein will be the "shoot," and all outside will be reckoned, for the time being at least, as "barren ground."

On the other hand, take the example of a fissure-vein, with straight parallel walls, and with a width of 3 ft. The filling is quartz-gangue containing sulphides, and the width does not vary for long distances. In certain portions the operations have shown that high values in gold and silver occur in the vein-matter, while other portions, indistinguishable by their physical characteristics from the ore, are practically waste-rock. I need not recall to miners, and to those familiar with mines generally, how frequently such alternations of rich and barren vein-matter occur.

The last case cited is, according to the present system of nomenclature, as much an occurrence of ore in shoots as is the instance of the vein of varying width in slate country, where the distribution of the shoots depended on the form of the original fissure. In the one instance the shoot resulted from physical causes; in the other the distribution of the shoots was due to chemical differentiation in the solutions from which it was deposited. Explanations of the selective activity exhibited by these solutions, resulting in the formation of shoots of ore, are, up to the present, largely speculative. In addition to the above two classes of ore-shoots must be considered those occurring in connection with fissure-veins in bedded deposits. In these the chemical action resulting in their formation has been in some cases controlled by physical causes. A consideration of them is hardly pertinent to the point I have raised regarding shoots in fissure-veins.

I can hardly allow to pass one point made by Mr. Collins in his valuable letter. In Fig. 2, of the illustrations accompanying his article, he shows "a case which is typical of perhaps the largest number of ore-bodies in fissure-veins." The shape of the ore-body figured by Mr. Collins, I am inclined to think, is of a rather exceptional kind. From the context it is to be inferred that Fig. 2, of Mr. Collins, represents a shoot of ore in a vein. Shoots of ore in fissure-veins, as they have been defined above, my experience has induced me to believe, have in the majority of cases a lenticular form, whatever their origin. A definite pitch in the plane of the vein is generally characteristic of them. The pitch may make any angle with a horizontal line representing the strike of the vein. The longest axis of the shoot may form a right angle with this horizontal line, or again the longest axis of the shoot may coincide with the horizontal, constituting the "course" of the Cornish miner. The main point I wish to make is that, in the majority of cases hitherto noted, it has been found that the longest axis of an ore-shoot is a straight, or nearly straight, line, and not a curved line in the sense figured by Mr. Collins.

My contention is not that ore-shoots of very irregular form do not occur, and the above criticisms and remarks are offered mainly in the hope that those who have observed the phenomena extensively will record the results of experience. The literature of ore-shoots is not ample, and no one will deny that the subject possesses much practical interest and importance in its relation to the mining industry.

C. W. PURINGTON.

Denver, Colo., March 24, 1903.

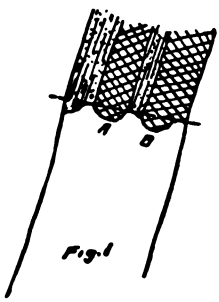
The Editor:

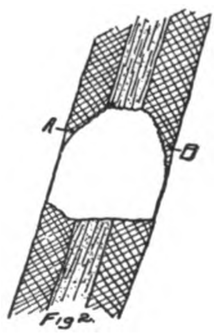
Sir.—This excellent series of articles is without question the best presentation of the difficult and important subject of mine sampling that has yet appeared; nevertheless, there are, I believe, a few points that have not been treated as fully as their importance demands, and some others where there is at least room for discussion as to the better practice. As Mr. Rickard says, "No two men set to work in exactly the same way." Each person naturally believes his own system the best or he would not follow it. Consequently, I propose briefly describing the methods that have in my experience given the best results in such cases.

Size of Sample.—The engineer having decided the proper distance between the points of sampling, it next becomes necessary to determine the safe weight of the original sample, taking fully into account the nature of the ground and its breaking qualities. The sample is then estimated at so many pounds per foot in width of the vein. In gold and silver mines from 2 to 10 lb. should cover the limits in ordinary cases, and an average of, say, 5 lb. per foot will usually be found quite safe. Thus a vein 10 ft. wide would give a 50-lb. sample. This factor determined for the particular vein under consideration, the samplers should be instructed as to the width and depths of the sample cuts required, and, as a check on the accuracy of their work, the samples should be weighed, and those exceeding 10 per cent. variation from the adopted standard rejected. The irregular weight of samples is a fruitful source of error in mine examination because the excess weight invariably comes from the softer and usually richer portion of the vein, or else it comes from loose or shattered rock containing, in its fissures, concentrated vein material not rightly belonging to a true sample. Large samples are usually a mistake in the systematic sampling of a gold or silver mine, and so we rely on "The smallest sample consistent with securing a true average of the lode at each place sampled."

Marking the Position of the Samples—Where arbitrary distances are chosen for the points of sampling, the position of each cut should be marked off in advance and tied to cross-cuts, survey stations, and other prominent marks, so as to check up with the general plan of the mine. The position of each cut is best marked with a number, preferably the sample number, painted or chalked on the rock at one side of the workings; this facilitates re-sampling, or the examination of the cut, as one can walk directly to the point. It is a great advantage to the engineer to be able to examine the sample cuts while they are yet fresh, and, having with him the assay value of the ore, he will then quickly see from the nature of the mineral exposure those places that appear abnormally high or low and order the re-sampling accordingly.

Examining the Places to be Sampled.—After the position of the proposed sample cuts is established as above explained, the vein at the places marked is carefully examined, brushed, or washed clear from accumulated dust,





mud or dope, and irregular projections knocked off, so that the cut will be practically at right angles to the dip of the vein, or, at least, a straight line across the ore to be sampled.

In Fig. 1 the hard portions—A, B—should be removed before sampling.

Fig. 2 shows at once one of the most difficult samples to take, as well as the most fruitful source of error in mine sampling. I have usually seen in such cases the ordinary sampler make a cut around the back of the drift from A to B, say, 8 ft., whereas the vein would not be over 6 ft. wide, and so reported. To accurately sample such a section is well-nigh impossible, and so it is often advisable to shoot off the wings on the walls, preparatory to sampling.

Taking the Sample.—A moil and hammer are the best all-round tools for the sampler, though a heavy pick in medium ground will usually give a thoroughly even cut and hence a correct average. A box to catch the cuttings is perhaps as good and convenient as anything; it should not, however, be much, if any, wider than the cut, particularly in vuggy or porous ground, as the pounding may shake loose (and into a larger box) more or less fine and possibly rich material, from outside the sample cut, and so salt the sample. Where this sort of thing is suspected, it is best to use one's hand to remove or catch the chips or rocks as they are loosened by the moil.

Where two sets of samplers are employed, I invariably work them together, giving one the odd and the other the even numbers; this helps to eliminate the personal element, and tends towards uniformity of practice. It is also safer.

Checking the Sampling.—It is always expedient to resample a certain portion of the cuts, say, from 5 to 10 per cent, varying on the importance of the work. Where the examining engineer is depending on assistants to do the regular sampling, these check samples should be his especial care. When samples cannot be assayed at the mine or in the immediate vicinity, the engineer is at a considerable disadvantage. In such cases he must, as a safeguard, take a large number of check samples, particularly of the more important cuts, say, not less than 20 per cent; otherwise he may have to pay a second visit to the property for the purpose of checking up some of the sampling, which, from the look of the charts, may not conform to other work and may, or may not, be correct. In most important mine examinations an assayer forms one of the party, and the samples are assayed on the ground. In such cases check samples should be taken immediately the work is started. These thoroughly test the whole process of sampling in the mine, the cutting down of the samples, and also the assaying. It is only such work as this, checking the original assay, that gives one confidence in the methods employed, and at the same time serves as a perfect safeguard against salting.

When all possible precautions are taken, two samples from the same cut across the vein will seldom check with that exactness expected from original and duplicate samples taken by sampling machines from a lot of crushed ore. In a recent examination I decided to re-sample in the original cuts two strips of poor ground occurring in shoots of pay ore. Here are the results:

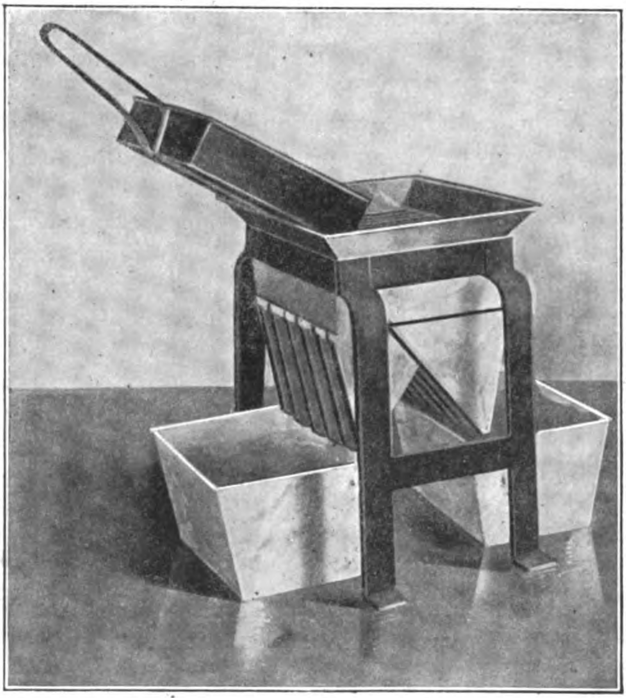
	Orig. sample.	Re-sample.
	$2.54	$3.54
	2.30	1.50
	2.71	2.57
	2.18	3.35
	1.98	1.35
	1.76	0.88
	1.27	1.25
	1.26	1.87
	2.32	2.60
Average,	$2.035	$2.10

	Orig. sample.	Re-sample.
	$1.17	$1.39
	1.57	1.39
	1.24	1.84
	1.68	1.50
Average,	$1.41	$1.53

It will be noticed that while some of the assays run higher on re-sampling, others are lower, yet the averages of the nine originals and duplicates check to within 3 per cent. Thus it can be seen that averages cut quite a figure in mine sampling, hence many small samples are preferable to a few large ones. In another case, where the average values were running in the neighborhood of $240, one sample over 3 ft. wide assayed $1,258; a re-sample gave $1,208, and yet another $1,296, the average being $1,254, and the variations about 4 per cent from the original sample. I have another recent case in mind which will serve to illustrate more than one point: A line of check samples along a practically barren portion of the vein gave, as was expected, a series of very low assays. One, however, ran $25.41, and a re-sample was called for. The same man took both samples, but with the re-sample he sent this note: "Sample probably salted; cut a small vug and fine ore ran out into the sample box." It was salted. The assay of the re-sample ran $102.74. I then sampled the cut myself, and, noticing a small seam of quartz containing some rich silver ore, I sampled that first, and the vein matter on either side afterwards, the result being as follows: 8 ins. of $151.60 ore; 1 ft. 3 ins. of $0.89 ore; 3 ft. 4 ins. of $4.47 ore; average, 5 ft. 3 ins. of $22.30 ore, practically confirming the original assay and showing that in certain cases the box as a means of catching the samples chipped off by the moil is, to say the least, misleading.

Sacking the Samples.—I prefer having the sample sacks plainly marked on the outside with a letter to designate the series, and a number, but not necessarily the number of the sample. One can then see at a glance and without opening the sacks just what sample it is, and can give them to the assayer in any order one may choose, preferably, however, in serial numbers. The check samples, taken as the work proceeds, also receive a serial number, having, however, no relation to that of the original sample. The small samples are at once tied up in their sacks, placed in a large sack and taken along by the samplers as the work proceeds.

Cutting Down Samples.—Where nothing better is at hand, a board platform, covered with a sheet of canvas, as described by Mr. Rickard, answers admirably. A small rock-breaker is, however, much preferable, and with it at least two sets of riffles and pans should be provided, to the end that the samples can be riffled down from the first in a rapid, accurate and cleanly manner, and all coning, quartering and brushing up from sheets or plates abolished, and with them many sources of error. For this class of work I prefer a form of riffle known in the trade as the Jones sampler, the safest, neatest and most expeditious apparatus for cutting down samples that I know of, and one that I have used for several years with perfect satisfaction. The sampler consists of a series of riffles, say, ½ in. wide, but instead of being U-shaped, as the ordinary riffle, the bottom slopes downwards at an angle of 65° (Fig. 3). The sampler is made up of a series of 12 or more riffles of uniform width (Fig. 4), soldered firmly together so that the spouts are alternately right and left; thus ore that enters the first riffle would be deflected, say, to the right, that which passes the second, to the left, and so on. It is supported on a stand (B) and the metal pans (C) placed under the discharge from the riffles on either side (Fig. 3); a small shovel with turned-up sides (Fig. 5) is provided of the exact width of the riffles. If the sample to be cut down is crushed in a laboratory breaker,



THE JONES SAMPLER.

the sampler shovel can be placed to receive the ore as it drops out of the jaws of the machine; this crushed ore is then leveled off to a uniform thickness on the shovel and gently emptied across the central axis of the riffles. Should the latter consist of six pairs, then one-half the sample will fall in six streams into the right-hand pan, and the remainder in six streams into the pan at the left. The sample is thus divided into two equal parts, the result of 12 cuts in one single operation. The contents of one pan is taken for the sample, it matters not which; the other is rejected. The sample is then crushed finer and the op-

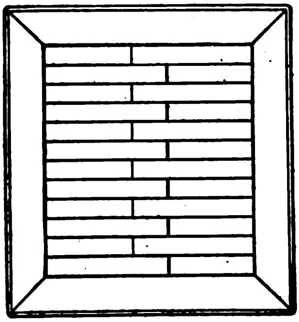


Fig. 4

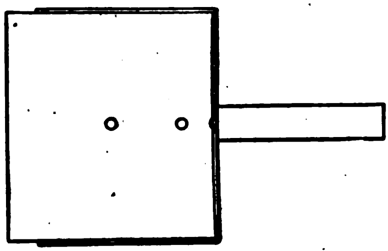


Fig. 5

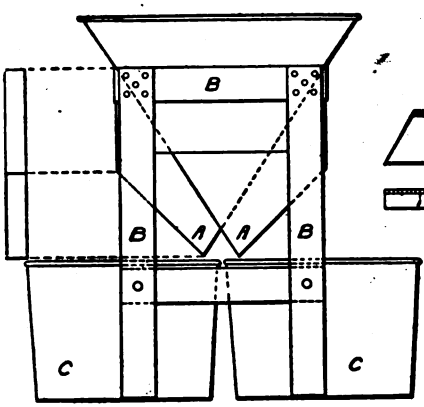


Fig 3

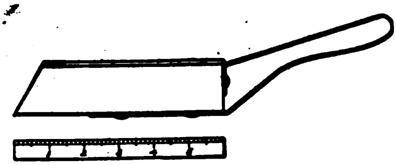


Fig. 5.

eration repeated after the sampler is brushed out and clean pans placed in position below the riffle spouts. The operation of crushing finer and passing through the riffles is repeated until the sample is reduced to the weight and mesh required. It will be noticed that no sheet or cloth of any kind is required nor is it necessary to spread the ore on the floor or on plates, that the ore comes in contact with metallic surfaces only, to which precious metals cannot stick or become entangled, as they so often do in canvas, in brushes and in brooms; while the errors, the labor, and the superstition of "coning and quartering" are eliminated.

All samples should be put up in duplicate, and in such manner that reliable assayers can determine their value to within 1 per cent. In order to accomplish this desirable end, the samples should be reduced to pass at least a 100-mesh sieve, and this work, be it remembered, rightly falls to the sampler and not to the assayer. The latter cannot be held responsible unless reliable samples are furnished him. Furthermore, no careful engineer could afford to trust the ordinary assayer's helper to cut down and reduce his samples. It is only when the samples are reduced to 100-mesh and put up in duplicate that the engineer is through with his part of the business. It is folly to divide samples of coarse ore and send them to rival assayers and expect the work to check; like as not, both will be wrong. Where there are no facilities for bucking samples at the mine, and the engineer has not brought the necessary apparatus with him, samples can be reduced to, say, 20 or 30-mesh, the finer the better; they should be put up in stout paper sacks for shipment from the mine, and then ground and cut down in the office of the assayer in the presence of the engineer or his representative. Sampling is expensive. It must be done well to be of value, and in no stage of the proceedings is as much care necessary as in the final one of cutting down the samples. This work is often relegated to the assayer's assistant, who, while competent for ordinary routine work, preparing specimen assays, etc., yet rarely has the training or ability to prepare samples for assay in the manner that smelters and sampling works find necessary and mining engineers should demand. The samples taken each day should, where possible, be reduced to the smallest limit before evening, put up in paper sacks, and placed under lock.

Erratic Samples.—The proper treatment of erratic samples is always a difficult matter. Mr. Rickard has given both sides of the subject very careful handling, and little more can be said. Where re-sampling confirms the original high result, the inference is that the values are there, and it remains to make the proper disposition of them. When examining for an intending purchaser, I usually first reject the erratic, high samples, if under 10 per cent, and determine the average value of the remainder. Next, I insert the average value so found as the assumed value of the higher assays, and estimate the block of ground on that basis. Where erratic samples are numerous, their relative importance to the whole number of the samples must be taken into account, as well as the amount of ground that they strictly represent, remembering that any given block of ground is not likely to maintain as high an average stoping value as that shown by sampling. When erratic samples run low and re-sampling confirms the result, they must stand. The whole object of sampling being to establish the average value of the ore, it is well to remember that it is not an exact science; consequently, in computing results, each man will, to some extent, be governed by his experience in determining the factors to be used, so that his final estimates will conform to the actual production of any given block when stoped out. This is what we mostly strive for, and the engineer who is 25 per cent below the actual value in his estimates of "ore developed" is as culpable as he who is 25 per cent above.

In a former issue of this JOURNAL, I attempted to describe a classification for ore reserves in different stages of development, and also for ore to be developed in the ordinary course of mining. These definitions have been discussed together with the articles on mine sampling, so I ask the same liberty of reply. "Ore in sight," I am pleased to note, has no defenders. Mr. George E. Collins appears to take exception to any method of classifying ore reserves, but gives an example of estimates made by his brother where the classification I suggested is very nearly followed. I further note that the distinguished engineer for whom Mr. Collins made this classified estimate, bringing to bear a wide and varied experience in such matters, unqualifiedly indorses my classification, using, however, the phrases "positive ore," "probable ore" and "possible ore" for those suggested by me.

Mr. Collins objects to my definition, "ore developed"—exposed on four sides—because, forsooth, some such blocks have been found, in certain cases, "to enclose a large barren patch in the center," though why it should be in the center instead of any other part of the block, is not stated. Others have found a rich patch in the interior of a block, and can with equal propriety object on that account. These matters have nothing whatever to do with the proposed classification; they are taken care of in the factors the engineer employs in making his estimates of net values. It appears to me that Mr. Collins does not quite understand the significance of my classification. The real point is not seen in the comparison of one vein with another, but in the various stages of development in one and the same vein. Where ore exposed on four sides can be more safely estimated than ore hidden, say, on two or more sides, the former, being a safer estimate, is properly placed in a separate class.

The geological and other conditions necessary to be taken into account in estimating the production of a given block of ore, and applying the factors of correction, are so fully treated by Mr. Rickard and also by Mr. Purington, that it would be absurd for me to attempt to add another word.

Mr. Collins next calls attention to the expense of opening out a mine in blocks of 150 ft. by 300 ft. His ideas are apparently connected with low-grade veins, and not over good mining. Taking the other extreme of values, by way of contrast, I have seen winzes sunk that produced over $1,000 worth of ore per foot (in one case $1,500), and they were placed at less than 50 ft. apart. Between these extremes the blocks that I suggested, with winzes or raises at intervals of 300 ft. or of 200 ft., will, I believe, fairly conform to the best modern practice. The ore-body shown in Fig. 2 by Mr. Collins is not typical of anything I have ever seen, and such is the opinion of others. That an ore-deposit of that shape may occur is admitted, but that it is "typical of perhaps the largest number of ore-bodies in fissure veins" is denied.

A final word on my suggested system for the classification of ore reserves. We will assume the various blocks in a vein have been measured, sampled and carefully examined regarding their geological environment, and that the engineer finally decides that a factor of 10 per cent should be applied as a deduction from the values shown in the blocks exposed on four sides; then, everything being equal, this factor of safety should be something like 15 per cent for blocks with one concealed side, 20 per cent where two sides are concealed, and something like 33 per cent where only one face of the ore is exposed. While on development these partially exposed ore blocks may equal, or even exceed, the averages found in the fully developed blocks, still the chances are that they will not, and a careful engineer will limit his risks in a manner something similar to the above factors, if, indeed, he will be willing to concede any estimate for ore exposed only on one face.

PHILIP ARGALL.

Denver, Colo., May 28, 1903.

The Editor:

Sir.—It would seem from Mr. Philip Argall's references, in your issue of June 13, to my criticisms of his former article, that we are arguing somewhat at cross-purposes. I certainly did not object to the classification of ore estimates. What I do deprecate is the adoption of cast-iron definitions for such classes, which will not admit of variation with varying conditions. To illustrate: I object to using the same expressions to denote estimates of ore in a pockety fissure-vein and a comparatively régular impregnated bed, merely because both are exposed on one, two or more sides, as the case may be.

I did not suggest that my brother was the originator of the division of ore-reserves into the three classes of "positive," "probable" and "possible" ore. I believe he adopted the idea from Mr. Arthur Winslow, who has made use of three similar classes in his Liberty Bell annual reports for years past. Mr. Winslow, however, using his own discretion and relying on his personal judgment as to the mine he is dealing with, is far less exacting in his requirements as to number of sides exposed than Mr. Argall, Mr. Lawrence, or the late Mr. Arthur L. Collins. He carries out, in fact, the principle that "the amount of evidence to be required when making estimates of ore-tonnage, and the number and nature of classes into which estimates should be divided, must depend on our general conclusions as to the nature and permanence of the ore-bodies in the mines under consideration, the distance between the workings, etc."

In figuring the ore-body No. 2 in my letter I did not mean to imply that that particular shape was typical, but that similarly irregular ore-bodies are "typical of perhaps the largest number of ore-bodies in fissure-veins." The regular ore-shoots of the text-books, in fact, are not very common in the field.

I think Mr. Argall may fairly be asked to explain what he means when he speaks of my ideas being apparently connected with "not over-good mining." It will be remembered that I was discussing the mining of irregularly-occurring ore-bodies in fissure-veins, as to which I will venture to state two propositions:

1. It is not, necessarily or usually, good mining to open up such a vein in blocks of 150 ft. by 300 ft. Each case must be decided on its own merits.

2. Any expenditure in the working of such deposits beyond the minimum necessary to discover and extract them may assist good experting. It is not part of good mining.

I did not, however, object to the expense of opening up a mine "in blocks of 150 ft. by 300 ft.," but to expense in raises, etc., for the sole purpose of blocking out irregular ore-bodies, and not necessary for their economical exploitation; working mines, in fact, for the best showing rather than for the greatest profit.

Are we not all apt to forget, at times, that mining engineers exist only for the sake of the mines, and not *vice versa?*

GEORGE E. COLLINS.

Denver, Colo., June 22, 1903.

The Editor:

Sir.—The article by Mr. Argall, in your issue of February 14, on the merits or demerits of the old-fashioned expression of "ore in sight" is of great interest to the profession, and the result of the different views which it will bring forward should induce a change in terms such as, it appears, is very much needed.

Taking advantage of the opportunity of discussing this subject, I would suggest the following terms:

Ore Blocked.—Such bodies as are accessible on all sides, that can be accurately measured and thoroughly sampled, and the values of which can be reliably determined.

Ore Partly Blocked.—Those bodies that are only partially developed, and the values of which can only be approximately determined.

Ore Faces.—Would designate those bodies that are exposed on one side or show only one face, and whose values can only be determined in a prospective manner as deduced from the general condition of the mine or prospect.

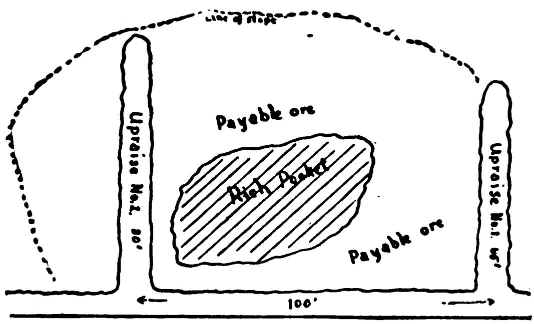
G. M. GOUYARD.

Denver, Colo., Feb. 20, 1903.

The Editor:

Sir.—Referring to the discussion regarding "Ore Developed," kindly allow space for this bit of experience from actual practice.

There had been blocked out on three sides a piece of ground as shown in sketch. The result of sampling showed the block to be payable ore, though with but a small margin of profit remaining above mining and milling expenses. Upon stoping the ground, there was encountered a pocket of ore within 6 ft. of the upraise No. 2, which carried a value three times that of the result of sampling the block, and which amounted to about one-third of that of the whole piece of ground.



This is a reverse, though more desirable case than the ones referred to in Mr. Collins' article of February 24, in which the ground might have been poorer instead of richer. It, however, illustrates the same principle of uncertainty with which we have to deal.

JOHN C. TREADWELL.

Sahuayacan, Mexico, April 6, 1903.

The Editor:

Sir.—I was very much interested in an article by Mr. Philip Argall, in your issue of February 14, in regard to the use of the term "ore in sight." What Mr. Argall has to say is very much to the point, and quite agrees with my views upon this subject.

I would use the following terms to qualify and more fully explain the purely general expression of "ore in sight":

1. *Positive Ore.*—Ore exposed on all sides.

2. *Probable Ore.*—Ore exposed on two or three sides.

3. *Possible Ore.*—Ore below the lowest level, or, as Mr. Argall expresses it, "below the last visible ore."

The use of these three simple words is recommended to engineers.

BENJ. B. LAWRENCE.

New York, Feb. 21, 1903.

The Editor:

Sir.—Mr. Collins now defines his position as objecting to "the same expressions to denote estimates of ore in a pockety fissure-vein and a comparatively regular impregnated bed, merely because both are exposed on one, two or more sides." Here we differ radically, assuming, for the sake of argument, such an unusual phenomenon as a "comparatively regular impregnated bed"; the engineer would use a lower factor of correction in dealing with the latter than in the case of a pockety fissure-vein, to the end that in either case his estimates may be as near correct as he can get them. So long as mines are developed by levels and winzes, or the counterpart of the latter—raises—the present method of estimating ore reserves in blocks will in all probability prevail and a block with all sides exposed will also receive a higher estimate than those with one or more concealed sides. In my definition "ore developed," I stated that as a general rule "the smaller the blocks of developed ore the more accurately can their contents be estimated"; suggesting as a safe rule in such matters that the length of a block should not exceed twice its depth. Within the limits I gave, there is nothing very rigid about this. Then it must not be forgotten that other classifications are provided to cover cases of incomplete development; consequently I cannot see where the so-called "cast-iron" definition comes in, unless it is the requirement that first-class reserves should have no concealed sides.

It is good business, and good mining also, to know, within the limits of commercial accuracy, what materials or ore one can safely depend on; taking stock does not directly increase the profits in any business, yet it is usually considered imperative at certain intervals. Turning now to the hypothetical ore-body (Fig. 2 of Mr. Collins) to which I am again referred, I desire to state that there is no evidence in the sketch to justify one in assuming that the outer lines drawn by Mr. Collins to represent the boundary of the ore-body have any foundation in fact. Considering the peculiarity of the assumed form of the ore-body and the development given, I would construct the outline of pay-ore as shown by the hatching, and, while this would give about 60 per cent less than Mr. Collins finds, I believe it is as much as a careful engineer dare allow on the development outlined.

PHILIP ARGALL.

Denver, Colo., July 11, 1903.

UNSYSTEMATIC SAMPLING.

The Editor:

Sir.—I have been much interested in your articles on the systematic sampling of mines. May I contribute a few remarks upon the un-systematic sampling of mines in order to point out that, like all other good methods, systematic sampling has its limitations?

That these limitations are not generally recognized is indicated by the fact that certain large mine investment companies are reputed to go so far as to formulate rules by which their scouting engineers are bound. Two such rules I have encountered more than once and they are substantially as follows:

1. No ore shall be considered as "in sight" unless it can be sampled at regular intervals on at least three sides.

2. A purchase is not to be recommended unless there is a fixed percentage of the purchase price in sight.

Now, I think, the making of any such rules as these is open to criticism from a business standpoint. They are not conducive to the acquiring of good mining investments. I can, in fact, recall an instance where a good opportunity for a profitable purchase was lost in this way, and I have no doubt many of my readers can recall others.

The scheme of systematic sampling is based on the idea that mineral deposits occur in definite and measurable shapes, as, for instance, a fissure vein or a mineralized stratum, but we know from experience that a very large percentage of all mineral deposits are most irregular in shape and size, and in such deposits it seems to me that systematic sampling is apt occasionally to be actually misleading. By systematic sampling I mean the taking of samples across the lode at regular intervals on all the accessible drifts and entries with a view to figuring out the ore in sight from the measurements and assays thus obtained.

That there are limitations to this system can be shown by recalling a few irregular ore-bodies. Take, for instance, the Richmond mine at Eureka, Nevada; the Copper Queen mine at Bisbee, Arizona, or the Cortez mine at Cortez, Nevada, all of them mines which are identified with bodies of great value and magnitude, but of such erratic form that I cannot see how the ordinary methods of sampling could be applied at all; or consider the countless silver-lead deposits which occur as connected, or partially connected, chambers in limestone. How, may I ask, is one to figure the ore in sight, according to rule, in such cases?

Adopting Mr. Philip Argall's very valuable suggestions as outlined in your paper of February 14, and applying them literally, one could figure no "ore developed" in this class of deposits. Even blocks developed on four sides are like as not to be solid country rock in the center, and yet, in mines of this class there are frequently hundreds of feet of development with ore on from one to four sides of the passages. It is obviously most unjust to say this is all ore "being developed" or ore "expectant," and it should not be forgotten that these pockety and irregular deposits have contributed very largely to the world's supply of metals, and have produced some phenomenal dividend payers. It seems to me that, in cases of this kind, rules must be in a large measure disregarded, and the value of the engineer's report will depend entirely on the man and not on the system.

Take again the matter of outcrops; gold outcrops often assay more, and the outcrops of silver, lead or copper veins often assay less than the average of the shoots beneath. The outcrops of the famous Nacozari copper mine was a large mass of iron gossan, showing only a little copper carbonate here and there. The big copper mines at Cananea presented a similar appearance on the surface. Obviously, in cases of this kind the judgment must be guided much less by sampling than by mineralogical and geological indications.

What alternative is there to take the place of systematic sampling? The question is hard to answer, except in a general way that the method of sampling must be fitted to the individual case. Mines are such unsystematic things at best that no two will stand exactly the same treatment, and as I said at the outset, this contribution is intended to accentuate the limitations of systematic sampling, and it is obviously impossible to prescribe any system for a procedure which is essentially un-systematic, but I will give two examples which I hope will illustrate my point, and I can show that even in those cases where systematic sampling fails us there are still avenues of procedure, which, if they fail to give the concise data which are desirable, do at any rate provide a way by which a fair estimate can be made of a mine. In both cases the examinations were made by mining engineers who take the highest rank in the profession.

The first case was that of sampling a large gold mine in Mexico. The engineer spent two days poking around the mine with a sampling pick, studying the vein and the ore-occurrence. He put in the evenings studying the shipments and acquiring general information concerning the conditions of the locality. Now, in studying the vein he found that there were three or four distinct kinds of ore exposed in the workings and his wide experience in such matters enabled him to make a close mental estimate of the respective amounts of such ore in sight, so it only required a few samples of each kind of quartz to give him, at one stroke, data from which he could form a very fair estimate of the mine. These samples were taken and assayed under his directions, and I know that the returns from them led him to a correct opinion of the mine; for, although he at once proceeded to sample the mine in a systematic manner, the vein being one which yielded itself readily to such an operation, and although he and I kept in touch with the mine until its decline, he never had occasion to change his opinion.

The above example shows how a man gifted with good judgment can get at the facts without systematic sampling, but it is also an example of the fact that no thorough engineer will ever neglect so valuable an aid as systematic sampling wherever such a method is at all applicable. By treating the various mineral constituents of a lode we find a way, hardly a system, by which much valuable information may be gained. Every mine shows different kinds of ore, and very often they are of such a nature that having once educated the eye, by assaying the various kinds, it is entirely possible to distinguish the different grades on sight. In deposits of very erratic shape the information to be gained in this way may be very considerable, and may lead to a comprehension of the deposit which will facilitate systematic sampling afterwards.

The second case was that of a large copper-silver deposit which I sampled with the other of the two engineers previously alluded to. Here the ore-bodies left standing were so shapeless that the ordinary methods of sampling and measurement were utterly useless. He went at once to the pith of the matter by taking a few general samples, examining them carefully and separating them by concentration into their constituent parts, namely, clean concentrates, middlings, slimes and tailings. These various parts were each carefully inspected, accurately weighed and assayed, and with the knowledge gained thereby he was able to go through the mine and decide correctly, not only as to what was ore and what was waste, but he could pass upon the concentrating qualities of the material. This method of sampling showed the instincts of the metallurgist. The location of the mine was such that concentration was the only practicable treatment. Like the last example, this was a case of educating the eye, but it differed in that the eye was educated to read in values and percentages of concentrates as well as in values of crude ore. To this experienced metallurgist it was a useful "short cut" to results, but, like all short cuts, I imagine it might be dangerous to a beginner. The question of structural geology was also interesting in this case. The owners considered the deposit a large chimney, and worked it with the idea that the ore went down, found it did not go below a certain level, let the mine partly fill with water and put it on the market with the usual tale of inadequate pumping machinery. The deposit proved to be a large anticlinal fold with the axis dipping slightly to the east. There was more ore and more water in the eastern part of the mine than anywhere else, and the chance that the ore might continue along the axis seemed tempting enough to justify a little work. This interesting question, however, has not been completely solved as yet.

Another case will serve to illustrate my theme. I lately investigated a large low-grade deposit in Colorado. The lode is a brecciated band, in a schist country, about 200 ft. wide and two or three times as long. In this case also the structural geology is far more interesting and vital a question than the sampling, but as this is an article on unsystematic sampling, I will speak only of the conditions which affected that part of the work. The brecciation was complete and coarse; by this I mean that large open spaces had been formed as would occur in a pile of rocks. Some of these spaces were filled nearly solid with chalcopyrite which carried $35 in gold per ton and many others had only a little chalcopyrite, the remainder of the filling being a loose sinter, and both it and the schist contained very little of value. In fact, 50 per cent. of the values lay in these nodules of copper pyrite. As the mine had been worked by lessees it was only natural that the surfaces exposed underground were destitute of copper nodules. Here was a case where systematic sampling with a moil and hammer would result in error, but where the method of taking samples by car-load lot and shipping the same to the smelter would give useful information.

I cannot resist the temptation to say a few words in regard to the method of sampling "by car-load lot." One cannot but feel a little cheap and inefficient with a sackful of carefully reduced little samples all carefully tied up and sealed, when confronted by the man who believes in "sending a car-load to the smelter and getting your money for it." Somehow this "sending a car-load to the smelter and getting your money for it" has such a grand and practical sound to it, that it impresses people. But let us follow the car-load to the smelter and see what is done with it. Do they take a nice, clean furnace and smelt that car-load separately and weigh up the values from the results? Oh, no; they just put it through a sampler, which often is none too clean or too carefully handled, and reduce the car-load to one little assay sample. It is a noticeable thing also that the man who believes in taking his samples by the car-load is generally the same man that believes in hand-sampling at the smelter in preference to machine sampling. So that the man who does his sampling by car-load lots does his buying on one assay sample, while the other man does his buying on the results of many dozen assay samples, and, I believe, that each one of the many may be made as truly representative as the machine-sampled car-load.

I have just shown an instance where car-load sampling was needed, but in the majority of cases, I think, the sampling by hammer and moil is preferable, because it can be made to yield, not only the average value of the ore in a given block of ground, but the quantities and qualities of the various grades as well.

I hope that I have succeeded in calling attention to the fact that systematic sampling is only one of many tools at the engineer's command. Just as the skilled mechanic uses now one tool and now another, when the work before him changes, so the engineer may find it advantageous to vary his methods.

GEORGE J. BANCROFT.

Denver, Feb. 17, 1903.

ON SAMPLING THE FLOOR OF A WET LEVEL.

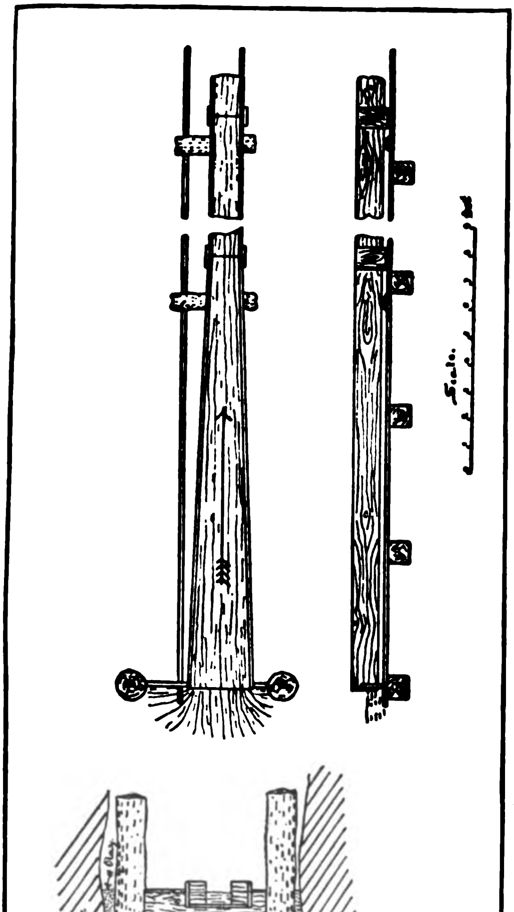
The Editor:

Sir.—I have read the articles by Mr. T. A. Rickard on sampling of ore with great interest, and it gives me pleasure to contribute some data upon one branch of the subject which has lately come within my experience. I refer to the sampling of the bottom of a wet level.

This is by no means a pleasant or easy branch of sampling; neither can the sample procured be expected to be as accurate as one taken in a back or wall, since the ore broken along the groove made by the moil remains more or less in place until collected by hand and, in doing this one allows many of the smaller pieces to escape. The tendency, therefore, is rather to obtain under-average values, because the richest ore is usually the most brittle. On the other hand, however, the cracks in the floor of a level form a good receptacle for, and in general, become filled with, the rich fines, and this would ordinarily tend to give over-average values; but, in the case to be described, water was always at hand, and by washing each sample carefully this source of error was eliminated.

All samples were taken in the usual way, by chipping a straight groove across the vein with the aid of a hammer and moil. In places we tried shooting, but found it unsatisfactory. The flow of water was about 300 gals. per minute, nearly all of which, in most cases, we successfully dammed back and carried in a flume over that stretch of level being sampled. The grade of the level was usually enough to keep the head of the flume higher than the discharge, but in places where the floor was flat or where it sagged, the difficulty was overcome by making the dam one plank or more higher; in all such cases the dam should be kept as low as possible, otherwise the unnecessary pressure behind it will accelerate leakage. The dam consisted of a 2-in. plank, 12 ins. wide and 4 ft. 6 ins. long, the level being timbered with sets, 4 ft. 6 ins. between the timbers, at 5 ft. intervals. The mud and loose rock were removed from the sill, and the dam spiked on it, all passages for water being stopped up with clay procured in neighboring workings of the mine, or with thick mud when the supply of clay gave out. Nailing the dam to the side of the sill was tried, but this failed to keep out the water as effectually.

The flume was 12 by 10 ins. inside cross-section, and was made by nailing together three 12 by 2-in. planks in sections of 16 and 9 ft., the longer ones being used for the straight parts of the level and the shorter ones for the curves. The inlet section was made wedge-shaped, being 1 ft. wide at its lower end and 2 ft. 3 ins. at the dam end; the latter end fitted into a recess sawn in the dam. On the lower end of each section, overlapping it by 4 ins., was nailed a collar, made of two 14 by 8 by 2-in. planks at the side and one 12 by 8 by 2 ins. at the bottom, and in putting up the flume the head end of each section was laid in the protruding half of the collar on the section above and made water-tight with clay. At first we had the collars made of 1-in. plank, but these proved unserviceable, because they were apt to be broken by the rough handling, accompanying the shifting of the flume. To give the flume a fairly even grade, it was blocked up underneath with timbers. With three samplers, taking samples at 10-ft. intervals, it was found that


Scale.
Country

a stretch of 200 ft. usually required a full day's work; the time, of course, varied with the local conditions; in this particular case the veins did not exceed an average width of 2 ft.

The way the work was conducted was as follows: On the previous shift a gang of men took up the rails, removed the loose dirt, which was one to two feet deep, and relaid the rails so that the flume could be brought in upon timber trucks. The rails were originally spiked to sleepers above the sills, but were relaid on the sills so that the track was lowered 6 to 12 ins. The flume was then laid on that side of the level opposite to that occupied by the vein. The places to be sampled were then marked off, and men were set to work to shovel the remaining dirt to one side and pick down trenches as far as the ore in place and bail out the water which oozed through. For bailing they used tomato cans. This was slow and tedious work; often it became necessary to build a small clay dam on that side of the trench from which the water came, or even all round it, or else to dig another trench just above the place where the sample was to be taken and bail from it.

If the vein be of such a nature that it breaks in slabs parallel to its strike, an accurate sample can be taken from under water; if not, it becomes necessary to make the trench dry because the muddy water prevents one from seeing what is being done.

Should the vein jump from one side to the other, it is advisable to take all samples on the one side first, then move the flume and take those on the other side. In regard to starting the samples at the lower end of the stretch first and working upwards, or vice versa, the local conditions of each stretch have to be taken into consideration. As regards working up or down the level, owing to the removal of dirt and lowering of the track, work must of necessity commence at the lower end.

The first day we used a 15-in. galvanized iron pipe in place of the flume, but found it unsatisfactory for many reasons. It takes too much time to put the sections together, also the pipe cannot be made to follow the bends of the level as easily as a flume can. It cannot be sawn or cut to any desired length as easily. By being open along its whole length a flume possesses another great advantage over a pipe. In the case of a cross-cut conducting extra water into that stretch of level being sampled, a clay dam with a 4-in. pipe leading into the flume was found sufficient to rid that part of the level of the extra inflow. The water bailed from the trenches could be poured straight into the flume, whereas with the use of a pipe much inconvenience and loss of time was occasioned by the water bailed from the trench above running down and filling the lower ones. The cost of the pipe was 95c. per foot, and that of the flume 17c. (timber at the mine in question costing $20 per 1,000 ft.). Except in the matter of weight, which, on account of the small amount of moving necessary, is of no moment, it is obvious that the flume possesses all the advantages.

The accompanying sketch shows the plan, side elevation and end elevation of the flume.

ERNEST LEVY.

Denver, Colo., Feb. 25, 1903.

The Editor:

Sir.—Referring to Mr. T. A. Rickard's excellent article in the JOURNAL of February 14 on mine sampling, permit me to offer suggestions on a few points. A gad made with an eye and fitted with a handle will be found convenient for taking samples in place of the moil Mr. Rickard uses. It is easier held in a variety of positions than the moil and more rapid work can be done with it. For the hardest rock the moil is better. For spreading the broken up sample, when coned on the canvas, a piece of thin sheet iron or tin, about 4 by 8 ins., will be found convenient; with it the same sort of even distribution can be made, by going round and round, that is obtained with the square-pointed shovel on the sampling works floor with larger samples. As a tag for the sacked samples, half of an ordinary manila express tag is excellent. The number is put on in duplicate with pencil, and the tag folded twice and put into the sack. This will resist any amount of hard usage that the sacks will stand. Wooden tags sometimes become illegible when samples are sent a long distance by express. In rich or otherwise important bodies of ore a good safety device is to divide the sample at the mine in triplicate, give each portion a separate number, send two sets to the assayer and reserve the third for control. This makes a check both on the assaying and the sampling. Only those control or triplicate samples are assayed in which discrepancies between the original and duplicate appear. This device is specially applicable in cases where the mine is remote and difficult of access and the sacked ore is taken away by the sampler. The use of it has saved the writer the necessity of a long and costly return trip and a re-sample. A discussion from Mr. Rickard of the advisability of combining several cuts across the vein at short intervals into one sample, or of taking separate samples at greater intervals, and in what cases each of these methods is preferable, would be interesting. This is a matter that requires judgment, and a decision on it has much to do with the time and expense required to make a given examination, as well as often determining the thoroughness of the work.

CHESTER F. LEE.

Seattle, Wash., Feb. 25, 1903.

The Editor:

Sir.—I have read your article on sampling with much interest. Personally, however, I believe in what you call "grab samples." Experience in buying ore has given me a fair judgment as to the average appearance of any special lot. In veins I like to know what each band of particular appearance runs, and especially I want the owner of the mine to show me the richest part of the lode, so that I may know its proportionate value with the rest of the vein matter, from which I take grab samples. These samples act as checks on the larger average samples taken. Now these, when put away in my pocket, have twice saved me from being "salted."

I think a man with experience can tell pretty well in most cases what is a representative piece of ore, and use it as a check on the average samples which are so easily tampered with.

For taking samples, I believe in a locked mail bag of leather, which will easily show punctures, and also blank samples already prepared to put in with the samples taken from the mine. This bag when taken underground is as safe a guard as anything can be against the samples being tampered with.

Large samples weighing a ton or more are, of course, best, but at mines unprovided with crushers, help is needed to crush them down, which increases the risk.

One man, whom I know, prepared little balls of clay containing gold washed out of the ore, which could be thrown from quite a distance into the pile without it being likely that they would be observed. A grab sample in this case would be all that would save one from a false estimate.

For young men your advice could not be improved upon, but each man as he gains experience has to be a law unto himself.

W. M. COURTIS.

New York, March 7, 1903.

The Editor:

Sir.—I have read with much interest the articles and discussions on mine sampling appearing in your Journal. I agree with Mr. Courtis that specimen or grab samples, representing the different classes of ore in a mine, are useful in sizing up the situation underground, and sometimes serve as a check on the other samples.

In sampling a vein where most of the values are in one or two streaks of friable ore and the remainder hard quartz, I have obtained good results by measuring and sampling the rich streak separately and figuring the average grade from the assays. This usually saves time in sampling, but requires another assay.

The information obtained is worth the cost of the extra assay, and to the mine operator it may save the cost of breaking down quartz too poor to pay, although the average across the vein, thanks to the pay streak, may indicate that all should be mined.

In a large vein there may be a streak next to a wall that will pay to mine, while the rest of the vein may be practically barren. A sample across such a vein would be wrong, and might indicate that the vein was too low grade to work.

In figuring averages, values, etc., the engineer's slide rule is very useful.

ALBION S. HOWE.

San Francisco, April 3, 1903.

MINE VALUATION.

The Editor:

Sir.—In reading the papers on "Sampling and Estimation of Ore in a Mine," it has occurred to me that a few remarks on South African practice may prove of interest to your readers, and in submitting them I am encouraged by Mr. Rickard's reference to the influence of the Rand on gold mining practice to believe that American engineers are keenly appreciative of methods used in the Transvaal.

No two gold-fields are exactly the same. To a certain extent each is a law unto itself. General rules must be supplemented by a thorough knowledge of local conditions. The importance of sampling varies considerably in different localities. For instance, suppose there is a huge deposit of low-grade material which must be quarried from a mountain. In such a case there may be little opportunity for selection. On the other hand, if you have to deal with gold-bearing deposits, such as those of the Witwatersrand beds, then sampling becomes of vital importance. In some districts sampling may be considered a desirable luxury; here it is an absolute necessity.

It has always been recognized on the Rand that sampling was of the utmost importance, but the mistake was made at first of imagining that anyone could sample efficiently. An applicant who professed ignorance of all mining matters was looked upon as a proper man for a sampler. All this is changed now. Whereas, one inefficient man was once considered sufficient for sampling, many of the big properties now employ at least two good men, who give their entire time to the sampling of the underground workings and the keeping of the records. Experience has shown that this pays well.

As is well known, before milling commences on a Transvaal gold mine, big ore reserves are blocked out, as much as 350,000 tons being usually developed by the time the stamps commence to drop. For a short period after the shafts first cut the reefs, the samples are generally assayed on an adjoining mine, or in the town. When the samples become numerous, the mine opens its own assay office. Sometimes, in the development stage of a mine, one man is employed to do the assaying and sampling, but it is considered better to keep the assay and the sampling departments separate. More often a man is engaged to do the sampling and surveying. As the mine opens out, more men are required, and when in full swing a property of 200 stamps employs a surveyor and assistant, an assayer and assistant, and a sampler and assistant. These six men are responsible for the mine valuation.

Before the war a fashionable way of developing a mine was to run what are known as intermediate drifts parallel with the main levels. In Fig. 1 a sketch of an intermediate drift is given. These drifts are started off east and west from the raise; and at intervals of 35 ft. or so, as at A A, box holes are blown through to the main levels. Not only was the main level carefully sampled, but the intermediate drift as well. The height of the intermediate drift was made one-half that of the level. Individual samples vary considerably, but over a long distance, as from 1 to 2, the average value comes out about the same. I am glad to say that the practice of running these intermediate drifts is dying out, for they are needlessly expensive.

During the development stage of a mine a frequent method of procedure is to sample the faces of the drifts after each blasting operation. This means an interval of about 5 ft., which is considered a fair distance between samples. The advantage of sampling the mine in this

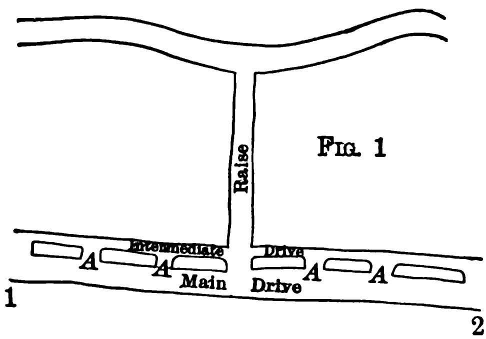


Fig. 1

manner is that the assay will show whether the miner is keeping on the rich seam, or "leader." The disadvantages are that, as a rule, the drift at the face is nearly choked up with broken ore, so that only one section can be obtained, and that the sampler is necessarily hurried by the miner, who objects to the delay caused by him. The same method is pursued in winzes and raises, samples being taken after every "round."

Mr. Rickard gives an instance of three samples being taken across a vein 12 ft. wide. On the Rand a sample over such a big width would not be taken, but the 12 ft. would be divided off into sections of 2 ft., and each section sampled separately. Look at Fig. 2, and you will understand why samples of sections are taken. In this example four distinct samples would be taken, one from each of the stringers, as it is of the utmost importance to find where the gold lies. Suppose stringer No. 1 persistently assayed 2 to 3 dwts., or much below the limit of pay-ore; then it would probably be decided to leave this stringer in the hanging wall and narrow up the stope. No matter if the stringers are thick or very thin, they are invariably sampled separately. On some mines, the waste rock found between the stringers is also sampled and assayed, but it is really only necessary to take occasional samples of this waste, as it seldom contains gold in payable quantity.

Let us suppose that there is an unbroken mass of aurif-

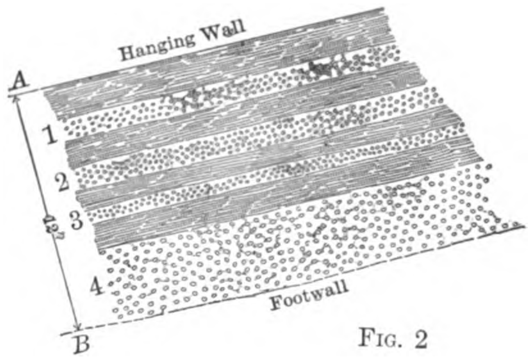


FIG. 2

erous material from A to B, 12 ft. wide, and that even below B there is still reef. Even in this case, according to Rand practice, the face would be divided into sections of 18 to 24 ins., and each would be sampled and assayed separately. For an ordinary drift showing unparted reef, the face is divided into three sections, namely, "hanging wall," "middle" and "foot-wall," and each section is sampled separately.

Thousands of tons of material on the main reef, which is the bulky producer of the banket series, are being left in the mines. As a rule, this material is too poor to be worked under present industrial conditions, but there are payable patches in it, and in the future more attention will be paid to the sampling of this material. An ideal way to test it is to use a diamond drill and get cores at regular intervals from the stuff which is left below the foot wall. In fact, it is likely that the diamond drill will become an important auxiliary in mine sampling.

In sampling drifts, winzes and raises it is found of considerable advantage for the sampler to make use of the surveyor's mine stations, for by so doing the exact position of each sample in the mine is determined.

On some parts of the Rand, where the reef is only an inch thick, it is a common practice to measure off equal distances on both top and bottom of the reef and take the sample over this width. If proper care is taken to get the right proportion of country rock in the sample, this method is a good one for small rich leaders. Of course, the calculation is made for a width embracing the waste rock sampled, together with the reef.

Some years ago panning was very popular on the Rand, but it has gone out of vogue of late. On account of the pyritic character of the matrix and the fact that much of the gold is "bound," panning can never be relied on for accurate determination on these fields, but as a rough test it is excellent. Panning serves three purposes: First, in a large mine that is being developed, where hundreds of samples are assayed each month, it is a check on the assayer's work. Then, panning gives a close approximation of the amount of pyrite in the sample, so that the assayer can decide whether there is need for a preliminary treatment for sulphur, such as roasting, etc. Lastly, in an office where hundreds of samples are being assayed in the course of mine valuations, I believe it would save money if the samples were divided according to the results from panning into rich and poor. The samples high in gold could be assayed by the scorification method, while the crucible would be used for the poor ones. I know some peoply decry the scorification assay and demand a "pot assay" for every sample, but with proper care I find the scorification assay satisfactory for rich ore.

The grouping together of all the assay values is entrusted to the surveyor, who, of course, is also responsible for the determination of the ore reserves. The assay plan contains the values of the samples taken in the mine, and it is this plan that the surveyor uses in estimating the reserves. Assay plans are made on one of three different planes, namely, the horizontal, the vertical, and the plane of the reef; the one which is best adapted for the purpose will depend upon the dip of the reef.

It is when the mill starts crushing and gold returns are reported that the mine valuation is finally tested. I must admit that it is somewhat discouraging to review the past history of the Rand and notice the difference between what was promised before the mill started and what was actually obtained when the battery commenced to work. If there was a constant in the discrepancy, it would be a simple matter to apply it to future determinations, but the results are too contradictory.

On one mine it was found that the returns from the reduction works were 70 per cent. of what the assay plan called for. On a neighboring mine this factor was subsequently employed. When the mill commenced crushing, however, much to the delight of every one it was found that a pennyweight more gold per ton was extracted than was promised by the estimates.

This goes to prove that the value obtained after sampling is not a mathematically correct figure, and that an engineer cannot always guarantee that the mine will give what the sampling calls for. In spite of such occasional discouraging results, sampling on the Rand is looked upon with more favor than ever, and with extended local experience the work of estimation is certain to be better done.

From what has been said, it must not be thought that the work of the sampler is over, or lessened, when the mill commences crushing. At all stages the sampler is necessary. After mining begins he watches the stopes most carefully to see that no payable material is left in the workings. From the stope samples, taken throughout the month, the value per ton of what the mill should return for that month is worked out. Every day a "lip sample" is also sent up from the mill. As inside amalgamation is now almost entirely omitted, only a spoonful of mercury being fed into the boxes every hour, with proper care a very accurate sample of the ore being crushed is given by the "lip sample."

I am glad to see that Mr. Rickard condemns the "grab" sample so emphatically. Better not sample at all than adopt this haphazard method. The only place where the "grab" sample is employed is in testing the waste rock leaving the sorting house.

Space will not allow me to enter into the discussion of ore reserves. The expression, "ore in sight," which appears to be causing so much discussion among American engineers, is seldom used out here at all. "Tons of ore developed" is employed, and care is taken to give the number of tons developed on each separate reef. As Mr. Philip Argall, in his suggestive contribution, has pointed out, the engineer should go into detail and give a precise statement as to the condition of the "ore in reserve." Almost invariably on the Rand the number of tons of ore in reserve are underestimated, due to too small a stoping width being assumed in the calculation. The question of stoping width is a very important one, for, if it is wrongly assumed, not only is the tonnage too small, but the assay value over the stoping width is made too high. At one time the stoping width was arrived at in the office, but

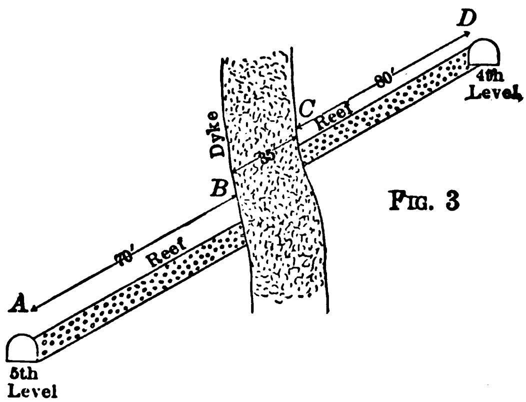


FIG. 3

now the custom is to examine every block of ground and work out carefully what the actual stoping width will be.

On those mines which have the misfortune to be cut up by dikes the management is at considerable disadvantage as regards ore development. Fig. 3 will illustrate a case. The dike cuts in two the block of ground developed by the fourth and fifth levels. Ordinarily, the calculation for reserves would be made f [illegible] from A to D. The general Rand practice is to only [illegible] the backs from A to B in working out reserves. [illegible] to D is not considered developing ground at all.

On most mines the [illegible] ground developed each month is usually at le[illegible] as the tonnage mined during that month. U[illegible]y just now, on account of the scarcity of labor [illegible] difficult to maintain a parity.

T. LANE CARTER.

Johannesburg, April [illegible]

SOME ASPECTS OF MINE VALUATION.

The Editor:

Sir.—As there are no gold mines in Scotland, I, a would-be valuer of mines, had to seek my ideals elsewhere. I found them in American methods. The American engineer goes at once to the vital point. He says: "*I want to know the net profit in sight in this mine.* On that one fact we will base everything. Don't bother me with details; just let us set to work to get the sampling through." At least, if he doesn't say that he ought to, because it is the one thing in mining that matters. Frankly, I have got "profit in sight" on the brain.

There is no marked cle[illegible] between the American and the English schools as [illegible] mine valuation; but an Englishman, as a rule, [illegible] less clearly defined idea of the net value of any [illegible] than an American. As a mine manager he is perhaps the better man of the two, but on the question of valuation he is not so clear. There is a certain haziness [illegible] slovenliness about English gold mining. Some of the [illegible] a ton of 2,000 lbs.; others, one of 2,240 lbs. We calculate our yields and our assays in the wearisome Troy weight, instead of in that

Sterling with which nature has supplied us. We put our best properties under the control of titled incompetents, and we write reports on mines so lacking in a grasp of the vital points that the compilers ought to be led out at sunrise and shot.

This slovenliness in the English system shows itself, naturally, in the all-important branch of mine valuation. We do not, it seems to me, rush in and grasp the one great fact—the profit in sight—as do Americans. We play round the edges of it, and our reports, which should be merely a statement of this fact in its several bearings, are made bulky with useless details and side issues. I believe that often, too, having got the fact, we don't quite know how to use it. We cannot crystallize it sufficiently into thought. If our fact, as is so often the case, shows the mine to be on the borderland of good and bad, in the region of doubt, we are afraid to say to our principal, definitely, either "yes" or "no." We try to shift the responsibility of the decision to someone else, and write a report which has no backbone or individuality about it. I think it takes a strong man to be a good mine valuer—a man to whom the taking on of responsibility comes naturally. You must know how to handle your fact to be successful. An able engineer told me that he judged his subordinates by the way they could condense a report into the limits of a cable; and the shortest cable meant the best man. I think he was not far wrong. *He* was an American.

English engineers often fall short of doing good work because they are unable to view the problem from their employer's point of view. They get their fact all right—that is to say, the net value of the mine—but they don't know how that fact ought to be set before the capitalist. To be a good mine valuer, a man must have the instincts of a financier. He must put himself in that particular financier's place. He would then realize how needful it is that his report should be a clear-cut statement, saying yes or no to each question and taking full responsibility. As it is, four out of five reports I read are written by men who hedge, who are weak on the financial aspect, and who leave an impression of vagueness that is exasperating. These same reports will be voluminous, and deal at length with side issues, but they don't satisfy one on the vital points. The system is wrong.

The environment of the English engineer is against him. In America the capitalist who sends a man to value a mine probably intends to buy that mine himself and work it; and as likely as not he knows nearly as much about mining as the engineer does. His first question to the mine valuer on his return is, "Well, what's the net profit in sight?" He takes the report and turns it inside out, and if in his several capacities—as mining man, financier and student of men—it fails to satisfy him, its compiler may understand that he has been "turned down." But the London capitalist is a man who does not buy mines to work himself. He is essentially a middleman. His life's work consists in educating a large public to come forward and buy the wares—good or bad—which he may from time to time offer them. He would hardly appreciate the significance of being told that he had got hold of a valuable mine. To him the great question would be, "Can I get the shares well introduced on the market?" On your returning from the mine, his first question would be, not "What is the net value of the ore?" but, "Can you lunch here to-morrow? I want you to explain your report to Lord So-and-So, who is to be our chairman."

The English school of mining is seen at its worst in Australia; that is to say, in Australian mines controlled and managed locally. Some of these mines—for instance, those at Gympie, Queensland—are pockety, and would be difficult to sample correctly, but four out of any five mines in Australia might be sampled with some exactness. The Australian, however, flatly refuses to sample any of his mines; he just goes along from one ore-shoot to another, picking the eyes out of each, and so far as this great mining continent is concerned—with the exception of West Australia, whose mines are owned in England—mine sampling, or valuation, is almost an unknown art. In the

Melbourne *Argus* on a Monday morning there will be the weekly reports of perhaps 300 local gold mines. In these the managers will describe development work as "exposed gold," "good gold," "pyrites," "colors," "pay dirt," etc., etc., but from beginning to end there will be no word of either systematic sampling, assay results, or estimates of ore reserves.

Now, mark the force of evil example. The gold mining industry in the Malay Peninsula was started by Australian prospectors, and they were succeeded by Australian mine managers trained to these methods. The principal mine there was the Raub. Some years ago I was asked to report on it, because of its failing to keep up to previous yields. The mine had been working for eleven years, and at that time had a 60-stamp mill. The manager had just written a report stating that there were 300,000 tons of rich ore in sight (value, about $20), and that the lowest workings showed no falling off in results.

Then I made the following discoveries: First, *that the mine had never been sampled;* second, that there were only 41,000 tons of pay-ore reserves (value, $9); lastly, that the lowest workings in the mine showed no pay-ore. This property at the time was valued at $6,000,000.

That was an extreme case—even under the Australian system—but it is a warning that careless mine managers might take to heart.

I started to write this article under the idea that I was about to make some profound remarks on the minutiæ of mine valuation—about sampling methods, irregular values, ore reserves, and so forth. But after reading Mr. Rickard on "Mine Sampling," Mr. Argall on "Ore Reserves," and other authorities who have lately spoken in this paper, my assurance is not what it was. They have left little loophole for any one coming after.

I have never allowed a sample to be broken down, except in my presence. However much I trusted an assistant, I could only accept the assurance of my eyes that the section in question was fairly represented by the 10, 20 or 50 pounds of ore going into the bag. Soft streaks in the ore generally mean richness—hard streaks, poverty. The adjustment of the two is a problem which only one's own conscience can satisfy.

I have my assays done in duplicate, especially so when there is a plant on the mine and I can take my own assayer. If the beads vary only slightly in weight, you cannot but feel the more satisfied with the eventual result. At the Chuquitambo mine, in Peru, a conglomerate ore assaying $5, in four samples out of five, my duplicate beads used almost to balance. For instance, a series would read: 4.01, 4.02—6.83, 6.85—2.31, 2.31—4.98, 5.00. When there is a big difference it is as well to re-assay the sample—not to take the mean of the two beads. I expect to be sampling a mine in Hungary shortly, where the ore carries tellurides; there I shall have the assays done in triplicate.

The question of high assays is a difficult one. Even Mr. Rickard handled this question gingerly. As he implied, it is one which varies with nearly every mine; it cannot be reduced to definite system. In some mines—but I think very few—the occasional high assay truly represents the nature of the ore. Mr. Rickard's example of the Tomboy mine, as falling under this heading, is also the one I would suggest. If the fantastic assays at Tomboy were eliminated, the ore would work out at an average recovery of $4 or $5—but it is actually double that. At the adjacent Camp Bird mine, the assays of which run into hundreds of dollars—and they occur rather often—are judged in their relation to the assays on each side, and, should those be much lower, are reduced considerably. For example, three following assays going $52—$165—$79 would be entered on to the plan, but in a series reading $5—$104—$11, the middle assay would be drastically cut down. In the Camp Bird there are so many very high assays that this method leaves the management with a something "up its sleeve," but, for accuracy, it is nearer the mark than putting every high sample on to the plan at its theoretical value. On the Rand, at least in my day, exceptional assays were rigidly reduced to something like the general average of the mine. I feel sure this was correct. The collapse of many of the outside Transvaal mines, banket and quartz, may be traced to the fact that their sampling was inefficient, and that their incapable managers had included all high assays at their full value. Mr. Denny has written very well on the subject of sampling on the Rand. This year I sampled a certain mine. I took seventy-five samples, of which four gave fantastic results, showing coarse gold. The general average without these was unpayable, so I was spared the trouble of even re-sampling at these spots. I included these four samples on the assay plan, giving to each a value four times greater than the general average without them, and thereby raising the general average $1 a ton. The result, curiously enough, brought the theoretical value of the ore out at the precise figure which some thousands of tons had already yielded in actual treatment.

As Mr. Rickard pointed out, you may either re-sample a rich spot or you may sample on each side of it, close up, and take the mean of the two. My own idea is that in a low-grade ore, especially one carrying regular values, a high assay is out of place. Even if I re-sampled such a spot a dozen times, and kept getting higher and higher results, I should still cut it down to the average. In a high-grade ore it would be more natural to find a few big assays, but I would not recommend the purchase of a mine on them—the margin would have to be represented without their assistance.

In figuring out ore reserves a mine valuer has got to take certain risks, for not one mine in fifty changes hands on the basis of net profit in sight. If the ore-shoot under valuation is of biggish dimensions and the lode well defined, I think the engineer is entitled to allow something for "good-will." In such a case, I should allow 25 or 30 ft. beyond the face of a drive in good ore; below a single winze I would allow 10 ft. and below two winzes not a great distance apart, 25 ft. A similar margin of risk would hold good at other development points. If the ore-shoot was a short one, or a series of short shoots, and the lode of "scraggy" appearance, I do not think I would make any allowance at all. In either case, one would be guided by the condition of neighboring mines.

Of course, it were better to be in the position of never taking a risk beyond, let us say, a block of ore exposed on two sides—but, as I have said, mines can rarely be bought on such conditions. The mine valuer knows that he is liable to error, and that the ore "assumed to exist" may turn out valueless. But if he is an honorable man, whose experience tells him he is justified in taking such risks, I see nothing wrong with the system. If a man is true to himself, he is not dealing falsely by his employers.

With the assistance of a good surveyor and draughtsman and of a reliable assayer, there is no reason why a mine valuer who is very careful, who is practical, who is experienced, and who, down in the depth of his heart, has confidence in himself, should not arrive at a fairly correct estimate of the intrinsic value of most ore-bodies. But he must be practical. In mine valuation, practice and theory are apt to clash rudely. I once sampled a gold mine which had previously been reported on by one who wrote after his name "Lecturer on Mining." He had fine credentials. This man, as a theorist, was in the upper ranks of mining, but in practice, as a valuer of mines, I found him, to say the least, eccentric. He satisfied himself with only thirteen samples altogether, although the workings were quite extensive; and from the results of these assumed the average value of 60,000 tons of ore. One block of 18,000 tons he valued on a single sample. Across this same spot my own sample gave $30 less than his, and the rest of the block, from samples taken every few feet, was still poorer. My valuation for the whole mine, from a big number of assays, worked out at one-third of his, and the tonnage at one-third. I do not infer that my own figures were necessarily correct; but those who style themselves "Lecturers on Mining" should realize that mines cannot be summarized in thirteen samples, nor 18,000-ton blocks of ore by single assays. This person, I believe, meant well by his report, but nature did not fit him with that practical and active nature necessary to a valuer of mines. As a plumber he might have been a success.

J. H. CURLE.

London, April 25, 1903.

The Editor:

Sir.—The interesting series of articles recently published in the JOURNAL upon mine sampling suggest comments resulting from the writer's own experience.

In the first place, it seems that the prospect pick should not be so summarily cast aside. In cases where the engineer is sampling small prospects, or must get along without an assistant other than a local helper whose sympathies are with the mine, it is possible with a proper use of the head and the point to get a fair sample. In the taking of check samples and for testing particular ore streaks it is very useful, if its weak features are borne in mind. The use of "pop shots" is admittedly unwise, but the flat cone resulting from their use is no more unfair than the numerous irregularities of face encountered in sampling. The salting of the dynamite is all but impossible, if the sticks are taken out of the original package and the miner has not been warned. Another point worthy of attention is the condition of the face to be sampled. This is very often dirty with mud, powder smoke, and dust. Aside from the actual danger of salting, always possible with dirty faces, it must be remembered that the rich ore minerals of many deposits are brittle and the fines are very rich. Such material may give false values to a sample taken from a dirty face. If the ore be very hard, the only way to get a clean face may be to use pop shots.

A word about the use of a box to catch the ore cut in sampling. If the ore be very hard it will fly off in chips, a considerable part of which will not go into the box; if soft streaks occur, all the material goes into the box. The result is an unfair sample. If a strip of canvas 20 ft. long be used and the width is sufficient to reach the sides of the drift, all the chips will be caught. There will be no danger of any one salting the sample by flipping in material, if the engineer follows the commendable practice of excluding every one from the workings but his own men. The use of the canvas is also an advantage if the ore be spotty, since it is easy to cut a number of narrow grooves at close intervals, letting the material all form one sample.

In quartering down the sample it is not always possible or convenient to use the method described by Mr. Rickard, especially in the examination of small and remote properties. If the usual method of rolling the sample on canvas be used, the fines will be more uniformly distributed if the canvas be rolled by one person, taking hold of opposite corners alternately and rolling with the cloth close against the sample. Too often caution is not used to brush off the dust when the rejected quarters are removed. Personally, I find a piece of white enameled table oil-cloth preferable to canvas in quartering down. It is quite as flexible and the glazed surface prevents the material from sticking, while the cloth can be bought at any country store.

In marking samples some engineers carry small brass disks with numbers punched on them. If used at haphazard, and the number entered in the notebook, identification by other parties is impossible. If numbers are put on the outside of the sacks, do not make them consecutive.

In extreme cases, as in long trips in Mexico, where the samples cannot be under observation all the time, it is safer to use tin cans made and taken out for this purpose and sealed after filling.

When inspecting a mine it is both good sense and economy to make a preliminary examination, and to take samples at long intervals. Personally, I believe it is good practice to take samples of foot and hanging-wall streaks, even where apparently barren, also of separate ore-streaks and lenses. It affords valuable information about the distribution of values and as to the advisability of sorting the ore. In my own experience I have found the waste of altered gneiss, constituting the vein-filling alongside of a vein of galena, to be full of cobweb-like films of rich silver ore (pearcite), constituting better ore than the galena, and yet this had been thrown over the dump for some time. The discovery of the Camp Bird by Mr. Walsh was, he tells me, due to his recognition of the value of a similar condition but of different character. In another mine I found the hanging was an altered andesite containing pyrite and carrying $60 per ton in gold, while the recognized pay-ore carried only $12 per ton. While it is true that the local miner generally knows the ore as well as, or better than, the examining engineer, it is well not to follow the miner in his prejudices.

The valuation of a block of ore being based on assay results, it is well to consider how these results should be used. The common method is to multiply each assay value by the width of ore at the point where the sample was taken, adding up the resulting "foot-dollars" and striking an average, to be used with the tonnage of each block to give the total value. In still more accurate work, two assays are made of each sample, and these are averaged. Another way, and one which has given very reliable results, is to average the values of two adjacent samples and multiply the result by the average of the two widths of the vein; the product is to be used as the value of that particular part of the ore block; the result is quite different from that obtained by the first method, as will be seen below:

Width	2	(6)	10	(6.5)	3	(2)	1	(5.5)	10
Value	$20	($11)	$2	($10)	$18	($14)	$10	($20)	$30

The average is $16.31, using the first method, and $13.45, using the last.

Dressing a mine for examination is easier than salting and more difficult to detect. If the ore occurs in bunches or small shoots it is an easy matter to carry up a stope as long as the ore is low grade, or the material is waste, and to stop work as soon as good ore is reached. In a certain Wood River property the mine was so well dressed that a reliable engineer figured that the ore developed was worth $450,000, and when it was worked it was found to be but $125,000. In a recent case a million-dollar property, with, what appeared to be, a safe margin of profit in the great blocks of ore developed, was shown by the work after purchase to have been similarly dressed for examination. The irregular workings of some mines and a lack of rectilinear development are likewise misleading. Where the workings follow irregular ore-streaks an ordinary calculation is apt to give a wholly erroneous estimate of the ore developed. This is particularly true of Mexican mines, where the irregular workings follow the ore in utter disregard of any other consideration, such as economy of extraction or systematic development.

WALTER HARVEY WEED.

Washington, July 7, 1903.

The Editor:

Sir.—Referring to Mr. Weed's letter of July 7, it seems desirable to call attention to the fact that his second method of obtaining averages is indefensible. Starting at the root of the matter, the true average of any set of samples is obtained by multiplying the value of each by the width of each and dividing the sum of the products by the sum of the widths. The average width, of course, in the case where samples are taken equi-distant is the numerical average of the widths. This has been explained recently in the series of articles in the JOURNAL that prompted this discussion; a little earlier Mr. A. G. Charleton referred to the matter in Volume IX. of the *Transactions* of the Institution of Mining and Metallurgy, and once at least in an earlier volume of our own Institute the subject has been discussed. All of these papers have been of admirable clearness, and will certainly bear re-reading at intervals by every engineer. In passing on, I would like to call attention to one detail: While the average value of the rock will truly be determined as above, the average stoping value of the rock in cases where the widths run down to a space smaller than that in which a man can work must, for correctness, be referred to least stoping width.

However, this is a matter aside. Returning to the question in hand, I append below a list showing the average values of the five samples according to Mr. Weed's two methods, substituting for his results those obtained by using the proper average width divisor, and the averages also worked out (rather as matter of curiosity) for the second method, but using true averages for the sections between each pair of samples. As a further explanation of this last let it be noted that Mr. Weed's parenthetical values in nowise represent the true values for those sections, as they are bare numerical averages, giving the same weight to a two-foot sample and a ten-foot sample. Thus he gives the average for the width between the first two samples as 6 ft., which is correct; he obtains his average value in the same way:

$\frac{\$20 + \$2}{2}$ **equals $11.00. The error is evident:**

$20.00 ×	**2 ft.**	**equals**	**40**	**foot-dollars.**	
2.00 ×	**10 "**	**"**	**20**	**"**	**"**
	12 "	**"**	**60**	**"**	**"**

$\frac{60}{12}$ **equals, $5, the true average for the first section.**

But there is another error that crops up in this method of sections or panels; it is that the three middle samples are used twice, the first and last but once; and as, in this case, the first and last samples are the highest, the resulting average is too low. Of course with a large suite of samples, such as would obtain in most practical work, this error would not be large, but it is hard to see any excuse for this method in mine valuation. The comparison is as follows:

True averages as given by Mr. Weed's first method . . . . $16.31 5.2 ft.
Average by sections, Mr. Weed's second method . . . . $13.45 5.0 ft.
The same with true sectional averages. . . . . $12.69 5.0 ft.

This comparison satisfactorily shows the extent of error easily obtainable by an incorrect system of averaging, which extends to width as well as value.

All of us, I fancy, have had experience of the matter mentioned in Mr. Weed's last paragraph, of a mine being "dressed for examination." It is the common dodge of the prospector, who runs well into a good "bunch," and leaves it for the engineer to sample and goes to another part of the property to repeat the "dressing." But there is another point, which calls for the careful investigation of the engineer: It is a common claim among promoters that the actual results from mill-runs furnish a better indication of the value of the ore reserves in a property than any amount of sampling, and this claim can be so plausibly supported that, by the investor at least, it is frequently accepted as truth. As a matter of fact the owners are apt to be pressed for money, otherwise they might not have wished to sell the mine, and in that case they are sure to have handled the better grade of rock, so that the result of past operations would not in any way represent the value of the ore left. I have a case in mind where the drifts were at times run very high. The high spots turned out to be in particularly good ore; in this case but little stoping had been done and considerable development, and until one had seen the property the claim that the value of the ore extracted represented the value of the ore left seemed a most plausible one.

R. Gilman Brown.

San Francisco, July 25, 1903.

The Editor:

Sir.—In common with many of your readers I have enjoyed the discussion that has appeared in your columns over the methods and details of mine sampling, and, in connection therewith, I am tempted to break the silence generally held by me, to mention an interesting incident of sampling that occurred in a mine in California.

The ore was the usual quartzose schist of the middle counties of the Mother Lode. About 50 lb. had been broken from a 12-ft. face of ore, and while wet and a little sticky, it was broken down to about ½-in. pieces; after the usual rolling and quartering upon ordinary cotton duck, it occurred to me that it would be interesting to take the two final quarters, crushed to about ⅛ in., and weighing about 10 lb., as two samples, and have them assayed separately, because it is generally assumed that the final quarterings are of equal assay value.

Much to my surprise one quarter assayed $14.80, the other, $3.90, in gold per ton. Upon inspecting the samples from other cuts, carefully, I found the gold occurred in small wires, and that these wires were sharp and very easily penetrated the cotton duck, so that a form of concentration was being effected the more the sample was rolled. To obviate the trouble the large samples were placed in a gunny-sack, brought to the surface and dried, and a canvas having a prepared or soft enameled surface was used thereafter in all work involving gold and silver determinations. The enamel of the cloth admits of a thorough admixture of the sample, and at the same time prevents the gold from adhering to the canvas—the action being similar to that of glazed paper in the laboratory.

I think it a great mistake not to have some means of identifying a sample after it has been closed and sealed, and a serial number, not necessarily the sample number, should always be placed on the bag as soon as the sample is sacked and tied.

RICHARD A. PARKER.

Boston, June 20, 1903.

The Editor:

Sir.—Mr. Richard A. Parker, in your issue of July 4, touches upon a subject of interest to those whose duty it becomes sometimes to sample auriferous deposits.

Mr. Parker's meaning, in the letter referred to, is not altogether clear. Does he mean that the concentration of the gold in the interstices of the duck took place *during* the rolling of the sample, which had been broken up to pieces about ½-in. size, or *after* the final quarterings had been crushed to about ⅛-in.?

If the former was the case, how was the gold transferred from ½-in. pieces of a wet and sticky quartzose schist into the pores of an ordinary sampling cloth?

If the concentration took place *after* the final quarterings, how does it come that those quarterings assayed $14.80 and $3.50, respectively? Why was not the concentration equal in each of the quarterings?

The question of gold being removed from samples and caught in the interstices of a sampling canvas, is an old one. The writer had an experience of a similar nature some years ago. The promoter of a gold mining property urged, as the cause of extremely low results obtained from a sampling of the various openings, that the writer had broken down the samples onto canvas, and quartered them down on same, rolling them over and over as many as twenty times or more. He enclosed with his letter a piece of the canvas to show how easily the gold could be caught in it. He failed, however, to explain how the gold got out of the quartz, for the samples were large ones, and the material was broken to about the size of hickory nuts.

W. L. AUSTIN.

New York, July 6, 1903.

The Editor:

Sir.—In your issue of July 4, 1903, Mr. Parker gives an example of the very indifferent results obtained by rolling and quartering samples on canvas sheets.

Every one, of course, admits that quartering samples on a canvas is not the most reliable way of obtaining perfectly accurate results. Still, away from railroads where one is obliged to pack for days, riffles not being made, as a rule, substantial enough to stand rough handling, nothing is left to the engineer but the use of a canvas sheet which can be replaced anywhere when necessary.

In the case cited by Mr. Parker, and where he found such difference between his two ultimate quarterings as to render the results useless, I hardly think that it was due to concentration on the canvas, but that the cause lay with the nature of the sample itself. Mr. Parker states that the ore was a quartzose schist, "slightly wet and a little sticky." Naturally, if the sample carried fine metallics which were set free by the partial crushing, these particles, as a matter of course, would be picked up by the larger "wet and sticky pieces" of the samples, which pieces acted, in fact, as clay does in a sluice. Under such conditions a fair sample can hardly be expected. As stated above, we all recognize that canvas quartering is far from being accurate, but still very close checking can be done with it.

The example given further on, although not at first intended to check canvas results, will, however, give an idea of how close results can be obtained by using ordinary precautions.

The following samples were taken from a quartz vein, ribboned in structure; the quartz was middling hard and carried small amounts of sulphides of iron, zinc, lead and copper. Three mill-runs of twelve hours each gave respectively 80, 83.34 and 87 per cent of the gold values on the plates; consequently the ore could almost be called free milling, notwithstanding the small amount of sulphides present. The samples weighed originally 30 to 60 or 70 lb., according to width of vein, and after being thoroughly dried they were crushed by hand to about quarter-inch size, and then thoroughly rolled and quartered down on a large piece of canvas, the owner of the mine securing the two rejected quarters of the sample.

The samples were assayed in Denver by a well known and reliable assayer and gave the results below, or an average of gold 2.333 foot-ounces, and silver 8.45 foot-ounces. Later I received the results from the mine owner, as giving an average of gold 2.42 foot-ounces, and silver 10.4 foot-ounces.

No.	Mine Owner's Samples. Ag. oz.	Au. oz.	Engineer's Samples. Ag. oz.	Au. oz.
1	5.60	0.87	4.13	0.87
2	13.70	1.16	12.00	1.00
3	3.26	0.44	1.33	0.40
4	17.38	1.31	16.00	1.28
5	6.12	4.52	3.72	5.08
6	3.80	1.74	2.00	1.40
7	5.48	0.64	4.00	0.56
8	13.12	7.58	12.40	8.00
9	16.42	1.07	15.00	0.88
10	6.61	1.04	2.47	0.93
11	8.05	5.78	3.42	4.48
12	4.17	0.35	3.00	0.39
13	7.52	1.32	4.20	1.20
14	15.60	1.45	17.00	1.26

The difference in the gold average of the two sets of samples is 4 per cent, which is close enough for all practical purposes; but the difference in silver of 19 per cent is rather large. However, taking into consideration that the assays from the mine owner were made away from any railroad, in Mexico, where supplies are not always standard, and also taking into consideration that his interest in the matter might have made him perhaps rather partial to the mine, the above results show that pretty accurate work can be done on the canvas sheet, when one is obliged by circumstances to use it. Ordinary care should be taken, samples should naturally be well dried and broken to about ¼-inch size, then carefully rolled so as to obtain a perfect mixture; if the mass slides instead of rolling on the canvas the ultimate quarters will be spotted, as a concentration in that case occurs; after each quartering the sheet should be thoroughly brushed with a stiff broom and close checking of the quarter's assays will invariably follow.

G. M. Gouyard.

Denver, Colo., July 27, 1903.

The Editor:

Sir.—In answer to Mr. W. L. Austin's queries in the Journal of July 11, I would say that the original sample was broken to about ½ in. before quartering and rolling began; the final samples were broken to between ¼ and ⅛ in. In a more or less clayey mass which had been rolled frequently it is impossible to say when the concentration took place, if indeed it was a concentration; the more the sample was rolled wet as taken from the face, the greater the tendency of the gold wires to find lodgment in the soft duck, or in the clayey film that readily forms after frequent rollings of such samples.

The differences in assay value were due to the greater number of gold particles in one sample than the other, and the reason these particles were not more uniformly distributed by rolling was due to the sticky nature of the material sampled.

Any one at all familiar with the auriferous schists of the Mother Lode of California would readily see the importance of the suggestion made: the difference between ordinary gold quartz and the schists named is apparent and readily accounts for the greater ease with which the gold particles leave the sample in the latter case.

The point I wish developed is the danger of quartering down ores carrying free gold, wet or damp, and doing this upon the ordinary canvas such as is generally used for such purpose; it is difficult to properly clean the canvas after each sampling owing to the sticky, clayey material that fills the interstices of the duck, and particles of gold left from one sample may be incorporated in the following one, thus rendering one too high and the other too low by the value of the gold misplaced. The samples should be fairly dried and then quartered upon canvas having an enameled surface.

RICHARD A. PARKER.

Saranac Lake, N. Y., July 17, 1903.

The Editor:

Sir.—In experimental physics it is often necessary to know how far the results are accurate after all positive corrections have been applied. The method of least squares is a mathematical process which accomplishes this by combining the limiting inaccuracies of the instruments and methods employed, and gives a figure representing the mean probable error of the final result.

In a mine only a very small portion of the ore is exposed to the sampler, and as the values are very unevenly distributed the mean probable errors are very large, as compared with those of other methods of measurement which we have to make. In a great many cases, the cost of mining and treatment being deducted, there is only a very small margin of profit left, and it is then important that the engineer should be able to represent to the owners or prospective purchasers how far the mine is a safe investment and how far a speculation.

If a block of ore is sampled and said to average A, we mean this as the nearest approach to its true average, which can be obtained by taking samples around its boundaries; the figure A may be somewhat too great or it may be somewhat too small. To be precise, therefore, we should say the average is $A \pm V$, where V is the mean probable error. Now suppose we have several blocks constituting a mine and averaging $A_1 \pm V_1$, $A_2 \pm V_2$, $A_3 \pm V_3$, etc., and weighing respectively M_1, M_2, M_3, etc.; then by the method of mean squares the average of the whole mine will be

$$\frac{M_1 A_1 + M_2 A_2 + M_3 A_3 + \text{etc.}}{M_1 + M_2 + M_3 + \text{etc.}} \pm \frac{\sqrt{M^2{}_1 V^2{}_1 + M^2{}_2 V^2{}_2 + M^2{}_3 V^2{}_3}}{M_1 + M_2 + M_3 + \text{etc.}},$$

which may be more conveniently written

$$\frac{\Sigma\, M A}{\Sigma\, M} \pm \frac{\sqrt{\Sigma\, M^2 V^2}}{\Sigma\, M}$$

The following is a tabulated example:

	M Tons.	A ± V Ozs. Per Ton.	M A.	M²V².
Block No. 1....	2,100	3.60 ± .32	7,560	451,594
Block No. 2....	5,800	4.50 ± .20	26,100	1,345,600
Block No. 3....	1,200	6.20 ± .55	7,440	435,600
Totals	9,100		41,100	2,232,794

$$\text{Mean} \begin{cases} = \dfrac{41{,}100}{9{,}100} \pm \dfrac{\sqrt{2{,}232{,}794}}{9{,}100} \\ \text{or } 4.51 \pm 0.16 \text{ oz. per ton.} \end{cases}$$

The mean probable error involved in the usual method of sampling cannot be deduced in any very rigorous mathematical manner, but requires certain broad assumptions. Suppose a square to be divided into eight equal

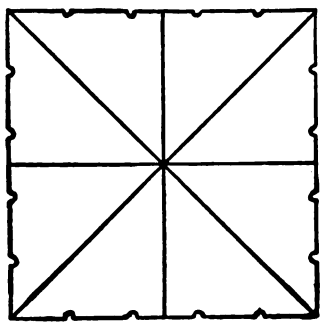


fig 1

triangular portions so that each presents an equal and similarly situated sampling face as shown in Fig. 1, and that two samples assaying a and b, are taken on each such face; then we may assume the average for the triangle, as far as can be ascertained from the face, to be

$$\frac{m_a a + m_b b}{m_a + m_b} \pm \frac{m_a a - m_b b}{m_a + m_b}$$

for each triangle, where m_a and m_b are respectively the thicknesses of the vein at a and b. The term

$$\pm \frac{m_a a - m_b b}{m_a + m_b}$$

represents the variation from the simple average to just the same accuracy as

$$\frac{m_a a + m_b b}{m_a + m_b}$$

represents that average.

If we now compound the averages of the triangle by the method of least squares, we get for the whole block:

$$A \pm V = \frac{\Sigma(m_a a + m_b b)}{\Sigma(m_a + m_b)} \pm \frac{\sqrt{\Sigma(m_a a - m_b b)^2}}{\Sigma(m_a + m_b)}$$

When a block of ore is not square it may be divided in a similar manner, as shown in Fig. 2. Greater accuracy (or a smaller variation from the average) is obtained by dividing off the ore-shoots separately where their boundaries are reasonably well defined; the results can afterward be compounded with those of other blocks of pay ore.

If the one below the bottom level is divided off into two 45° right-angled triangles, as in Fig. 2, a large value is obtained for V. This is illustrated by the following table, which also shows the method of deducing the mean variation where more than two samples to the triangle are taken.

	Sample No.	Width Ft. (m)	Assay oz. per ton (a)	Oz.-Ft. per ton (ma)	Variation from simple mean of ma (5.720—1.787&c.)
Triangle No. 1	1	2.6	2.20	5.720	3.933
	2	1.9	2.05	3.895	2.108
	3	0.6	1.09	.654	1.133
	4	1.3	.05	.065	1.722
	5	1.2	.07	.084	1.703
	6	1.7	.18	.306	1.381
	1 Totals			10.724	11.980
	1 Means			1.787	1.997
Triangle No. 2	7	2.0	1.22	2.440	0.279
	8	2.6	1.00	2.600	0.439
	9	2.3	0.30	.690	1.471
	10	1.6	0.80	1.280	0.881
	11	0.9	0.41	.369	1.792
	12	1.1	5.08	5.588	3.427
	2 Totals	19.8		12.967	8.289
	2 Means	1.65		2.161	1.381

From which we deduce

$$A = \frac{10.724 + 12.967}{19.8} = 1.197$$

and

$$V = \frac{\pm\sqrt{11.980^2 + 8.289^2}}{19.8} = \pm 0.736$$

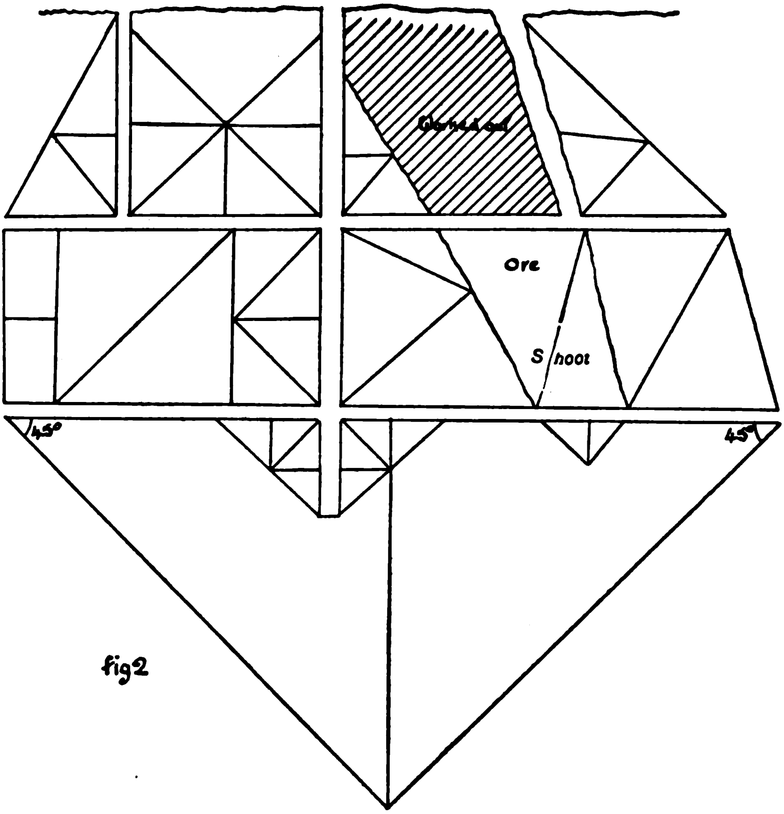


fig 2

The law of least squares only applies strictly where V is small compared with A, but in extreme cases, such as the above, V is none the less useful as indicating the low degree of accuracy of A; and although a more complex law may be used for these cases, it is obvious that V cannot be expected to be more accurately ascertained—with the same data—than A.

No attempt is here made to estimate the probable quantities of ore beneath the bottom level; we are dealing only with the degree of variation of value of given quantities of ore.

If greater certainty is required on a smaller amount of ore below the bottom level the assays may be divided among several smaller triangles, which will be equivalent to a row of rectangles of the same areas and bases. A will then remain the same, but V will be considerably reduced, and this should be done if the averages are to be combined with those of ore better blocked out. The same remarks may also apply to ore exposed on two sides; rectangles may be used instead of rectangular triangles, except at corners, but they should not vary much in dimensions from the ratio of 2 to 1, except in the cases where ore or barren ground evidently runs in shoots or horizontal zones.

The averages of all the ore considered payable having been combined in classes according to average value, mean error and other considerations and the method of mining and treatment having been decided upon, the value of the mine may be investigated by examining them severally by the following formulæ:

$$I = \frac{\$ \rho q}{100} (A \pm V) - \mu$$

Where \$ is the value in money of an ounce or unit of the crude.

ρ is the percentage extraction.

q is the tonnage.

μ is the sum of costs of mining, machinery, treatment and bank rate of interest compounded on the time the ore is to stay in the ground.

As regards presentation to the financier, I find the word "risk" is fairly well understood on Wall Street; 5 per cent risk is an even chance of making or losing 5 per cent on the investment and 100 per cent risk means an even chance of doubling or losing the investment. Therefore, if R represents the percentage risk, it is given by

$$R = \frac{\$ \rho q V}{I}$$

which becomes an appreciable figure even in the best developed mines.

Purely business men in the ordinary competition of trade do not expect to make more than bank interest on their capital and their salary as clerks without running some risk, but they make money in the long run by sound judgment of the comparative chances of profit and loss and by seizing the opportunities for the greatest probable profit at the least risk. The engineer who does not take proper account of the high assays obtained in fair sampling is therefore a poor adviser to the financier.

The use of the compound system of averages does away with the necessity for the use of such indefinite and artificial terms as "ore in sight," "probable ore," etc.; not only do the number of sides exposed count in determining the average, but the spotty character of the ore, the size of the ore blocks and the extent of the mine development are all properly compounded in the value V and make themselves known to the capitalist as the value R which he fully appreciates, and which ought also to be a guide to the engineer in recommending that the installment of machinery be immediate or deferred until the mine is further developed.

Just as much reliance can be placed upon V as a measure of the probability (or degree of "insightedness") of the ore as upon A, for whereas A has its origin in values of single samples which are very variable, so V is built up of differences of values of single samples which are not much more variable quantities.

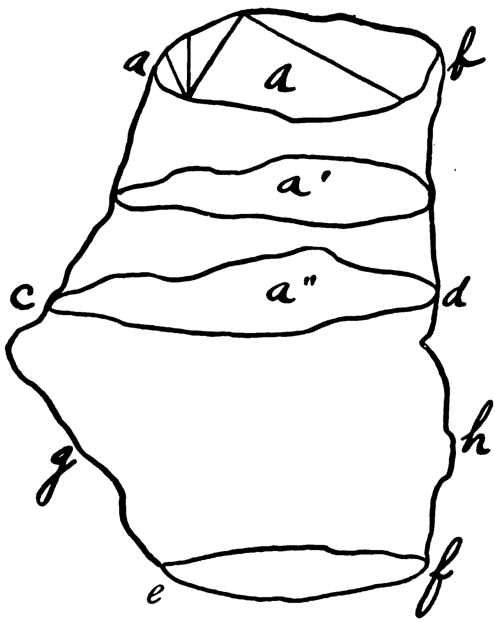
I have used these rules, with modifications to suit local conditions, for over two years upon every set of samples I have come in contact with, and now place absolute confidence in the reliability of the results.

BLAMEY STEVENS.

Valdez, Alaska, July 21, 1903.

The Editor:

Sir.—In the perusal of the articles on the estimation and sampling of ore-bodies which have appeared in your paper recently, and which, by the way, have afforded me much interest and pleasure, I have not noticed any mention made of the prismoidal formula in its application to the measurement of irregular ore-bodies. Some years since I discussed the value of it in one of a series of papers on mine surveying which I wrote for *Mines and Minerals.* The application of it is so simple and its results are so accurate in practice that I should think its usefulness would appeal to mining engineers, as it always has to civil engineers.



Naturally care must be exercised in its use; to illustrate, take a body a c g e f h d b, as shown by the accompanying diagram, the calculation would need to be made first for the smaller volume, a c d b, then for c g e f h d.

Re-entering angles must, of course, also be taken into account; but the three sections of a body being given—top, middle and bottom—their areas can be quickly ascertained by dividing the sections into triangles. The volume of the body, calling the top section a, middle section a′, bottom section a″ and height h, is:

$$\frac{a + 4a' + a''}{6} h$$

I know by frequent use both in the estimation of ore in mines and in piles, that it gives results accurate enough for practical purposes.

Another point I would like to bring up is the protection of mine samples. The value of accurate measurement and sampling of ore-bodies is self-evident, but to my mind the protection of the sample from mine to assay office is at least of equal importance. A device which has given great satisfaction to me, and which I have used for years, is a lead seal like that used by the express companies. The seal is of lead ⅝ in. diameter, ¼ in. thick, with two holes through its circumference large enough for a thin copper wire to pass through. When the sample bag has been tied with the wire passed through the seal the holes in the latter are closed by pressure of a die with a name sunk on one side and some mark or monogram on the other. Any novelty company will make such a die, and usually has the lead seals for sale. Samples, thus sealed, and locked in sole leather bags, also sealed, are safe.

The advantage of using this method as compared to sealing-wax is also apparent, where sampling is done in open-cuts or draughts.

AUGUSTE MATHEZ.

New York, August 12, 1903.

The Editor:

Sir.—I have followed with great interest your series of articles on "The Sampling and Estimation of Ore in a Mine," and with your permission will make some comment thereupon from the standpoint of the practice followed in the group of mines of which I am the technical head.

The function of sampling is now well recognized on these gold-fields as one of the most important contributions to the commercial success of the mines. The old-time haphazard method of promiscuous sampling, either by taking pieces of ore from trucks or "picking" down odd sections in the mine, has no present adherents, nor is the work of sampling relegated to the inexperienced "new chum,"* who formerly, if not thought intelligent enough for any other class of work, was provided with a sampling job. The enormously valuable part played in the economy of mining by systematic and conscientious sampling is now well recognized. A class of skilled, intelligent, alert men, culled largely from trained engineers, has arisen, and these have raised the status of mine sampler from inferiority to one of importance. It is gratifying to read that the peculiar and constant calls upon the integrity and will of the sampler have been duly acknowledged in the articles under review, and I believe the mine sampler will be encouraged and assisted to still greater efforts because of them.

In your introductory article, you dwell upon the fact that methods of mine valuation and examination have undergone very considerable development during the past decade, and you indicate the possibility that the close attention to this part of gold mining business on the Rand has, to some extent, influenced for the better the mining industry at large. Speaking as an Australian, and being also personally acquainted with American and European methods of some ten years since, I can cordially indorse the views which you have expressed as to the present advanced stage reached in the practice of mine sampling and valuation compared with the period I have named. Nor does the advance relate only to other countries; it is true no less of the Rand. The systems now in vogue represent the outcome of evolutionary growth, and are based upon experience and sound principles; but the writer well remembers some few years ago having to deal with assay reports and plans which were prepared and averaged in

*This is the colonial equivalent of our Western "tender-foot."—Editor.

the most elementary fashion, without any regard to widths of reef or intervals between sections. Now, happily, these instances are rare, and, in fact, so far as the Rand is concerned, things of the past; and the engineer is no longer troubled by enormous discrepancies between assay reports and milling returns, making, of course, the allowances which experience dictates as necessary between mere assays and actual recovery.

The engineer practicing on the Rand recognizes that here is, *par excellence,* the field which lends itself to the application of method. The banket beds, while fluctuating violently both in width and value in local areas, are unparalleled for consistency when considered throughout the Witwatersrand area, and the great range of development made possible by the natural condition of the ore and gold deposition give quite unusual facilities for estimation and the application of the law of averages. That these facilities have been recognized and embraced is undoubtedly creditable to the engineers, past and present, on the Rand, but it cannot be gainsaid that the conditions were such as to make the scheme almost self-suggestive. In looking back over one's past experience in other countries, and taking the natural conditions generally present in quartz deposits into account, whether these have been exfiltrated into previously existing fissures or segregations within rock masses, and considering further the small amount of development done upon the "prospect" which one was engaged to examine and value, and at the same moment transporting oneself mentally to the mines of the Rand, the conclusion is forcibly impressed upon one's mind how exceedingly advantageously situated is the man working on these fields, and how, in comparison, the risks of error he runs, given careful work, are minimized to the last degree in comparison with the engineer who is employed on deposits of a different character.

Mine examination in South Africa is shorn generally of many of the dangers present in pursuing similar investigations either in America or Australia. The mine salter, with his many ingenious methods of introducing gold either in the ore face or into samples, is unknown. The assayer who returns high-grade results from "grindstone" specimens has not flourished. The reason, probably, why there is no room for people of this class is that banket mining is essentially a capitalist's operation.

In quartz, or in other forms of ore-deposit, the metal worked may occur in rich bunches, which enable a prospector of limited means to collect sufficient of it to pay his way. In banket this is not the case, and therefore the banket bearing ground is sold on option to a company financially strong enough to exploit it. In the case of the examination of mines, the personal incentive to defraud for profit is wanting, because the mine is owned generally by a company, and individuals are not interested sufficiently to make it worth their while to seek means to create results more favorable than are actual. No claim can therefore be made that persons connected with the gold mining business here are more scrupulous than elsewhere. The simple fact is that opportunity seldom arises for an individual to perpetrate fraud for his personal advantage, owing to the special conditions of the case, and hence, having no temptation to err, all are alike honest.

I cannot quite agree with you, Mr. Editor, in your statement that "average value of the ore in the past can be ascertained from the records of a mine," if by "ore" you intend to convey the larger meaning of the exhausted portion of the mine. In my experience, I have found it just as necessary to make an inspection of the exhausted portion of the mine as of the current producing section, for the following reasons: Firstly, to prove to my own satisfaction that the mine has been fairly worked in regard to area of reef. It will readily occur to the reader that a mine can be easily manipulated to show high returns over a short period. Take the case of a mine which has two widely separated, narrow, rich shoots of ore. On such a proposition it would be possible to develop for a period of one year, and at the expiration of that time commence milling on high-grade rock. Assume that during the twelve months 100,000 tons of ore have been developed at a cost of £25,000, but that actually the rich pay ore represents only 25 per cent of the total tonnage. Then the charge for the redemption of the ore would have to appear in the working account as at 4 by 5, or 20s. per ton milled, and it is obvious that such a charge would require unusually rich rock to bear it. It would also be doubtful if a mine yielding so low a percentage of pay-rock could be developed fast enough to supply any but a mill of very small capacity.

The second reason why it is important to examine former workings in a mine under examination is to find out the relation between reef width and stope width. It has occurred in the writer's experience that the grade of a mine showed much lower than its mean average, because of including unpayable bands of reef or waste in the stopes for the purpose of showing low working costs.

Now, it is indisputable that mines should be operated for profit per ton, and such an objective as low operating costs is quite unjustifiable, excepting after the consideration of the main issue stated. I believe it will be agreed therefore that "the average value of the ore in the past" is not a criterion for the engineer to accept unquestioningly; otherwise, in the first instance quoted, he would be liable to have his judgment of the existing development prejudiced too favorably, and in the second instance the past records might lead him, even in the light of present satisfactory development, to put much too low a value on the mine.

Mines in New Districts.—You have plainly indicated some of the precautions to be observed by the engineer in estimating values of undeveloped mines in new districts, all of which are pertinent. It seems to me that one chief difficulty in estimating values in mines so placed is the want of facilities for observation. The engineer is called upon to decide whether a certain "prospect" is valuable or otherwise, and the available data upon which his judgment and previous experience are brought to bear are often meager in the extreme. Perhaps the points exposed are widely separated; he has no opportunity of studying dike

Form No. 99.

Meyer & Charlton Gold

MINE V

Duplicate

______ Shaft South Reef

No. 1 West (25 Stope) East Face

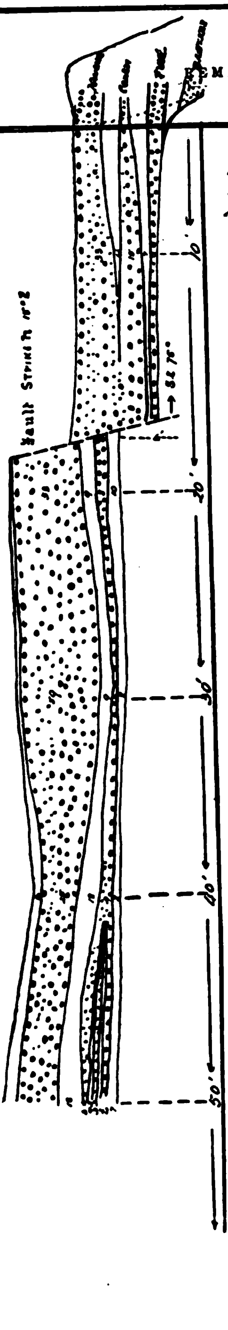
Mark on Sample.	Distance from. Centre of Level below	Width of Reef. ins.	Width of Waste. ins.	Width of Sample ins.	Assay of Sections dwts.	Stoping Width. ins.	Assay Value over Width Sampled dwts.	Assay Value over Stoping Width. dwts.	Assay Value over 36" dwts.	Assay Inches.
148	10' up	6		11	7.5					82.5
149	"	15		19	10.					190.
150	"	15		18	2.5	66		6.5		45.
151	"	18		18	6.5					117.
			10							
152	20'	8		10	5.					50.
			7							
153	"	14		16	9.					144.
154	"	18		18	6.5	82		4.		117.
155	"	21		21	1.					21.
			8							
156	30	3		7	8.					56.
			6							
157	"	13		15	12.					180.
158	"	16		16	4.5	86		4.7		72.
159	"	16		16	1.5					24.
160	"	14		15	5.					75.
			3							
			2							
161	40'	9		15	3.5					52.5
			15							
162	"	10		18	2.	72		1.5		36.
163	"	15		16	1.5					24.
			6							
			3							
165	50'	4		8	11.					88.
166	"	6		14	4.5					63.
			18							
167	"	17		18	1.5	88		2.7		27.
168	"	18		18	3.5					63.
			9							
						394				1527

Mining Company, Limited.

ALUES.

_10th_ Level _East_ Drive

Date _28/1/03_



REMARKS.

No 148 takes in Footwall Leader.
The backird is underlying as shown in sketch but is not exposed at 10' up

A Fault occurs just before reaching the 20' Section. Strike N.E. Dip approx 75° S.E. which throws the reef up 4'

Nos 153, 154, 155 forms one scattered body of pebbles.

No 161 takes in two distinct bands of pebbles.
No 162 takes in a 6 band of scattered pebbles in the top portion of it.

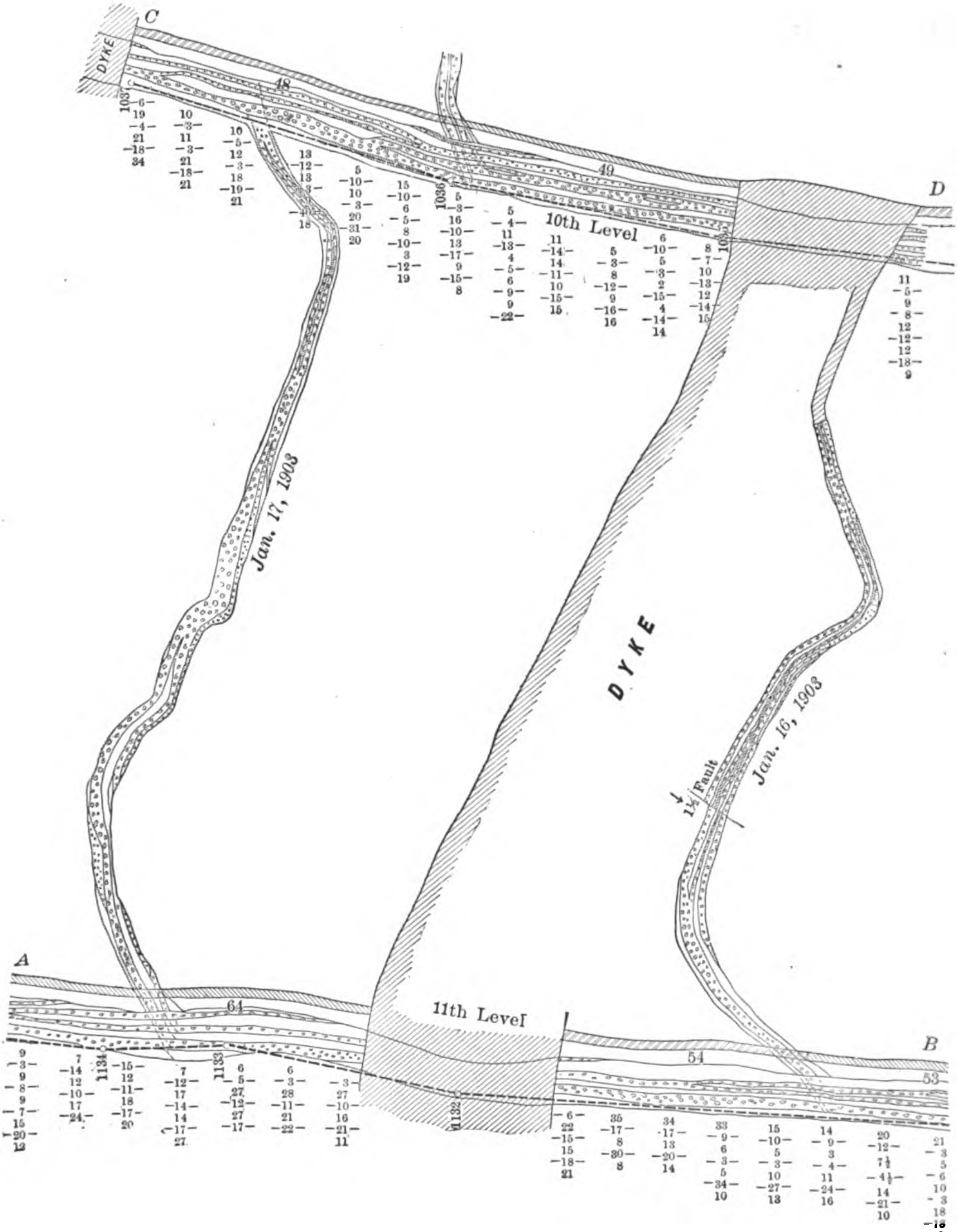
Leader compact in 165.

No 166 takes in two small bands The lower one is the best looking
Nos 167-8 form one compact body.

Denny

or fault effects, nor the probable width or trend of the shoot; nor, in fact, any of the vital factors entering into the ultimate consideration of the value of the mine as a commercial undertaking. He is therefore forced to one of two alternatives, either (1) to intuitively sum up the value of the property, or (2) to refuse to commit himself to an opinion until more work is done. The first alternative will always be avoided by the judicious engineer in favor of the second, both in his own interest and in that of his client; nor is it consistent with sound professional practice. The new district is always fertile in the class of property that is alleged to yield ore of the same grade as that in some adjacent successful district. In this country, for instance, it is usual to find the prospector or claim-holder filled with the conviction that as the working costs on the Witwatersrand approximate to 6 dwts. of fine gold per ton milled, he has only to establish the fact that he has 7 dwts. assay value in his ore to claim payability. He conveniently forgets, or probably does not know that from an assay value of 7 dwts. he can only recover by the ordinary processes 4.2 dwts., which would leave him 1.8 dwts. on the wrong side, figuring costs at 6 dwts. per ton. The engineer has therefore to be careful when fixing the value of a proposition to allow, as a margin of safety, that only 60 per cent of the original assay will be recovered. And here I would plead for the general expression of values in terms of currency, as—in speaking of gold—ounces may be fine ounces, worth 84s. 11d., or bullion, worth 50s. per ounce; and in all cases the estimated recovery values of ore per ton treated should be given and expressed as so much money value per ton.

The Cost of Mine Examination.—I observe with satisfaction that you have drawn attention to the cost involved in mine examination. In two recent instances of developed mines sampled under the writer's supervision the number of sections totaled about 5,000 in each case, the cost of assaying alone—apart altogether from the labor involved in obtaining the samples—amounting to an enormous figure. It frequently happens also that, prior to an ex-


C
DYKE
48
49
D
10th Level
Jan. 17, 1908
DYKE
Jan. 16, 1908
Fault
A
64
11th Level
B
54
53
1036
1134
1133
1132

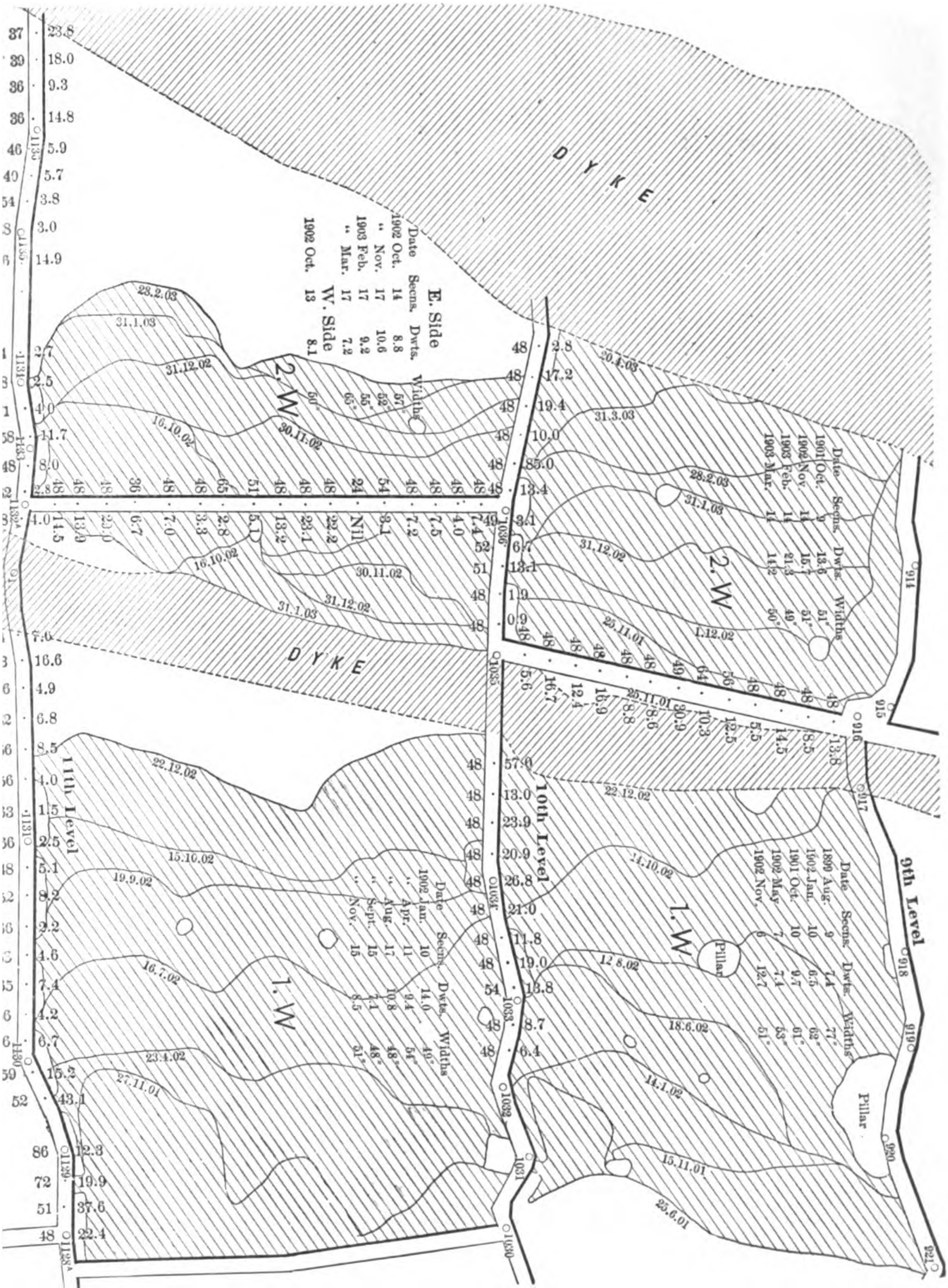
amination, the mine workings have to be cleared of water. This is an operation costly in proportion to the quantity of water to be handled. The writer has had instances of pumping amounting to over £1,000, and a monthly cost while the examination was in progress of £350 for this item alone.

The Sampling Interval.—In all mines under the control of the writer the sampling interval is 5 ft., and no longer spacing is, in his opinion, to be recommended. The preliminary examination made by the engineer ought to decide whether the mine is worthy of examination or not. If it be, then the 5-ft. interval should be adopted. I have found quite remarkable differences in sampling a length of, say, 500 ft., at 10-ft. intervals, and subsequently sampling again at intermediate points, and the difference as shown by the original 10-ft. sampling and the mean of the first and second has often been sufficient to reverse the conclusions arrived at from the 10-ft. intervals. The importance of taking the samples at regular distances cannot be over-estimated.

Sketching Samples.—The system of sketching samples, as employed by the writer, is illustrated herewith, and is based upon a scheme suggested by Mr. F. Burnham, now in the employ of the State Mining Department. This system gives in detail a longitudinal section of the shaft, level, or winze, in a continuous length, and is specially valuable when dealing with reefs having a tendency to split. The loss of any part of the reef is plainly denoted in the continuous section, and if of sufficient value the lost portion can be re-attacked.

Recording Samples.—The recording of the samples is plainly shown in the accompanying sheet, which is a copy of a sampler's usual return on the Meyer & Charlton Mine. It will be observed that waste rock is always separately shown, and in the actual sampling it is never sectioned, but simply measured.

Assay Plans.—Of these, two are kept, one being the ordinary outline development plan, and the other a continuous section plan. Specimen extracts from the actual


DYKE
E. Side
W. Side
2.W
1.W
9th Level
10th Level
11th Level
Pillar

plan are attached herewith. The scheme of the outline plan is to show both development and stope values, the width sampled appearing on the one side, in the case of levels, etc., and the value as upon the estimated stoping width on the other; the minimum stoping width for purposes of calculation being 36 inches. Referring to the plan, it will be seen that the widths are shown in blue and the values in red. The outlines between the levels show the stope faces for the various months, and the assay values are shown in general monthly averages.

If the widths of reef fall below 36 ins., the actual width of the reef is shown, but the value is calculated always upon a minimum of 36 ins., and appears as upon that width opposite the actual reef width, the reason being that we never estimate the stoping width as likely to be less than 36 ins.

The scheme of the continuous section plan is to provide details of each sectioned portion of the reef, and a continuous actual sketch of the reef in the levels. Referring to the extract, it will be seen that the sections sampled are shown separately, referring in each instance to the reef matter and waste in their alternate bands.

The average recovery value of the reef is shown on continuous section plan by different colors represented as under:

	Per ton.
Black indicates a recovery value of............	0 to 20 shillings
Blue indicates a recovery value of.............	20 to 25 "
Green indicates a recovery value of............	25 to 30 "
Mauve indicates a recovery value of............	30 to 40 "
Yellow indicates a recovery value of...........	40 to 50 "
Violet indicates a recovery value of............	50 to 100 "
Gray indicates a recovery value of..........	100 shillings and over

The recovery value (given in shillings) means the actual estimated gold per ton which, from the different processes, the ore will yield, and is roughly based on 70 per cent of the actual mine assay value, postulating a sorting basis of 20 per cent.

G. A. DENNY.

Johannesburg, Transvaal, May 11, 1903.

(Mr. Denny refers above to the colors used to denote various values on the sampling diagrams in use at the Meyer & Charlton Mine. The limitations of our printing-press have compelled us to substitute in the diagrams, cross-hatching for colors. The explanation is given on the diagram itself, on the page accompanying.

In reference to the sampling sheet, given under Fig. 1, it is well to add that the total of stoping widths, in inches, viz., 394, and the total of assay inches, viz., 1527, is carried forward to the end of a series of sections or lengths of drift or stope, when the latter is divided by the former, which then gives the average value in dwts. of gold per ton.—EDITOR.)

The Editor:

Sir.—The articles and discussions which have appeared in the JOURNAL for the past few months on the sampling and valuation of a mine have been exceedingly instructive; although I have read each week's contribution as it came from the press, yet within the past few days I have read the entire matter as a whole, and find there is more information in such a second reading than one obtains in the first perusal of the weekly editions.

The sampling of a mine is not an easy or simple task, although many self-styled engineers think it so and will often return from a mine with a few sacks of hand-gathered samples and then write a voluminous report as to the merits of the property and the value of the ore-reserves therein. Sampling is hard labor under the best conditions, and the actual moiling requires the skill of a good miner, carefully watched, of course; and I have found that good moiling is often foreign even to miners, not to mention the young and uninitiated who come west to get their first experience in mining by doing sampling work. I well recollect the incident referred to by Mr. Rickard in the issue of February 14,* when he says, "It took six men (three of whom moiled while the other three held the boxes to receive the sample) the whole of one shift to take three samples over a vein 12 ft. in cross-section, and in accomplishing this they dulled 35 moils." This incident was at the Camp Bird mine some three years ago, when it was first examined. The moiling was done by strong, able-bodied miners, and Mr. Rickard put me in charge of the sampling at the time. Many engineers regard the sampling of a mine as a perfunctory performance, to be gone through lightly, and they aim to accomplish the task in the shortest time and with the least trouble.

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*Page 19 of this volume.

All these points are well known to the readers of the JOURNAL, but I desire to bring them out again, in order to more fully emphasize the hazard and risk courted when the sampling of a partially developed mine is given into the hands of an inexperienced college graduate—often unaccompanied by the engineer in charge—who has come west to supplement his college training with actual practice in the field. This procedure has been adopted by some engineers in the last two or three years, but it ought to be discouraged. Unquestionably it is a cheap way, for the young men are very ready to undertake the work and at a reasonable figure, some of them being glad to go for their expenses alone. When an engineer is retained to examine a mine, his clients are entitled to all the knowledge of that property which his years of observation and experience are able to yield him; in fact, his experience, knowledge and integrity are all that is valuable to his clients, and he should give the products of such qualities to them unremittingly. It is obvious that any engineer can learn more concerning a mine under examination by being on the ground and overseeing the actual sampling, and sometimes taking a few himself, than he can possibly gather by going through the workings a dozen times and looking at the places sampled after the work is completed, especially in a wet mine where the fresh cuts soon become smeared. I have known of cases where inexperienced men have been sent out to a property for the purpose of sampling, even before their chief has been on the ground, and after the work was completed the engineer then came and walked through the workings and thought he thoroughly understood the chemical, physical and metallurgical conditions. One engineer of my acquaintance, and one who is well-known in this country and abroad, and with whom I was fortunate enough to be associated in my days of little experience, has gained an enviable reputation as a thorough engineer, and I attribute his success, in a great degree, to his thoroughness in sampling. He never intrusted this work to novices, and even when employing an experienced man he was present invariably and superintended the work; and to this day he will be found in his overalls, personally directing the sampling of any mine which he is examining. If one is sick and a surgical operation is necessary, is it satisfactory, after calling in the favorite doctor, to have him send a fresh medical graduate, whom he has known but a short time, to perform the operation, and after the wound is dressed have the surgeon arrive and pass an opinion on the case?

Please understand that I am not in any way criticising the employment of young college men; not at all; in fact, I am very much in their favor, for I was one myself; but I am decidedly against their being sent to sample a mine, without the constant supervision of their chief, long before they have had sufficient sampling experience or are capable of assuming such responsibility, because, as before stated, the sampling of a mine is not a simple problem, and I know of no other process in mine examination that is more important, or from which the engineer himself can gain more information. It is neither fair to the clients nor to the young men. I am glad to learn from the discussion that in several localities, especially in South Africa, the engineers in charge recognize the importance of mine sampling to the degree that the samplers are "culled largely from trained engineers."

Let me say, to those who take the trouble to transport over the country small hand rock-breakers for reducing samples, that three or four good men with short-handled hammers and old stamp-dies or hard rocks for breaking, with a canvas underneath, will break more rock, and do it quicker and with less fines, than an equal number of rock-breakers. I have tried them.

When there are two or more distinctly different vein-materials, or when the vein does not equal the stoping width, I have found that much better results are obtained by sampling each class of material separately, as it is impossible to obtain an average by taking the sample across the entire width with a continuous cut, because the different materials differ widely in specific gravity. With the separate samples it is an easy matter to calculate the average across the full width. This is the best way out of the difficulty mentioned by Mr. Argall, in the issue of June 13, in his Figs. 1 and 2.†

I have read the short articles of Messrs. Richard Parker and W. L. Austin in regard to the discrepancy in the assays of two quarters of a sample which was rolled on canvas. Mr. Parker gave it as his opinion‡ that the gold, which was free, very easily penetrated the duck, consequently the ore underwent a form of concentration. I agree with Mr. Austin§ that the gold does not penetrate the canvas; at any rate, the use of whisk brooms in quartering would remove it; and I am surprised that neither of them considered the fact that the sample was wet or sticky, for my experience is that most any kind of an assay can be obtained from wet samples, especially if they contain free gold. Without doubt the free gold was enveloped in the sticky material as the sample was rolled, and it certainly could not be homogeneously mixed through the sticky matrix.

As to numbering samples, I have used wooden, brass, hard rubber and paper tags, and I have found the latter to be the easiest and best. Use a tough bond paper in sheets about the size of a nickel tablet and use a pigment pencil. Write the number in the center of the sheet and fold it in the center, then begin at the folded end and fold to the size of a lead pencil and crimp it by folding over each end. In this way the number is folded in many thicknesses of paper, and I have found that these withstand rough handling in samples which are extremely wet. After the sample is reduced and sacked, beside the number inside I number it by a very small number, made with a lead pencil, inside the neck of the sack just as close to the string as possible. It can be found by the sampler, but it is out of sight and unknown to anyone else.

After trying canvas and boxes for catching the samples I find the box, a 50-lb. powder-box, is unquestionably the

† On page 104 of this volume.

‡ *Vide Supra* Page 151.

§ *Ante.* Page 152.

best thing to use. It can be obtained readily, and can be used in wet levels, awkward stopes, and anywhere in the mine. It will catch all the sample if held properly, and the samples are easily sacked from it. Mr. W. H. Weed does not explain how one can use a piece of canvas, 20 ft. long by 6 ft. wide, in wet levels, or at the top of high, narrow stopes.* The box merely requires the watching of an area of not over 4 square feet, while the latter necessitates keeping an eye out for dropping material from 120 square feet.

I would like to call your attention to a method of sampling which recently came to my notice. The incident is interesting only from the fact that it shows what a loose procedure may be employed when an engineer is in a hurry, due to the pressure of business expediency. But similar mistaken methods have been employed by others who had no such valid excuse and serious consequences have ensued therefrom.

The mine in question was a mine of some size, containing three levels and having some 935 ft. of workings. The report of the engineer read as follows: "Cuts were made across the full width of the vein from wall to wall at intervals of three feet," which should have made some 310 samples. Notwithstanding this statement, the valuation of the property was based upon the assay value of 29 samples as located on the section cut. Subsequent investigation and examination of the workings showed that the statements regarding the sampling were correct, but the results were arrived at in the following manner: Take, for instance, the triangular block of ground between the surface and levels Nos. 2 and 3. The sampling was begun in Tunnel No. 3 and samples were taken every three feet, then (and here is the dumfounding step) these 17 samples were all dumped into one large sack and labeled "Sample No. 1." No attention was paid to quantity of ore from each three-foot section. As each cut was made the width was taken, and the 17 widths averaged and given as the width for Sample No. 1. The same process of mistaken reasoning was fol-

* On page 145.

lowed in obtaining samples 2, 3, 19, 18 and 7, as well as the remaining 23 samples shown in the cut. The samples, as made up from the 3-foot cuts, also represent different lengths along the drifts. The value of the block was then given as follows:

No. Sample.	Value per ton.	Length, feet.	Width, feet.	Length factor, feet.	Width factor.	Total foot value.
1........	$10.86	50	3.7	5	3.7x5=18.5	200.91
2........	7.24	50	2.1	5	10.5	76.02
3........	10.58	40	2.5	4	10.0	105.80
19........	20.80	60	2.5	6	15.0	312.00
18........	18.34	40	2.5	4	10.0	183.40
7........	18.82	30	3.0	3	9.0	,169.38
				27	73.0	$1,047.51

Average width, 2.704 ft.
Average assay per ton, $14.35.

The above operation reminds one of that old ***reductio ad absurdum*** problem in algebra where, in letting a = b, the final result proves the startling fact that 2 = 1. The fallacy was in the assumption that $\frac{a - b}{a - b} = 1$. Just so, in the above method of sampling, the fallacy was in taking samples every three feet, throwing them into one sack and assuming the sack to be sample No. 1, or the average of the 50 ft. of drift from which they were taken. If such a process of elimination gave the correct averages, it is difficult to understand why it was not carried further and one sample obtained for the entire mine, thereby reducing the assay bill to $2.50.

Could one have guessed, for it was guesswork, the value of the property after it had been sampled by such a method, whether it was worth $500,000 or $100,000? Fortunately the mine was afterward sampled correctly and carefully at 10-ft. intervals and in accordance with the best methods, such as have been outlined in the articles on this subject in the JOURNAL, resulting in the taking of some 150 samples, and you will readily believe that the difference in the gross value of the ore, as arrived at from the two methods of sampling, in a property of this size, although containing only 935 ft. of workings, amounted to

$95,009.59! The description of the two methods affords a sufficient explanation.

F. H. MINARD.

Denver, Colo., August 15, 1903.

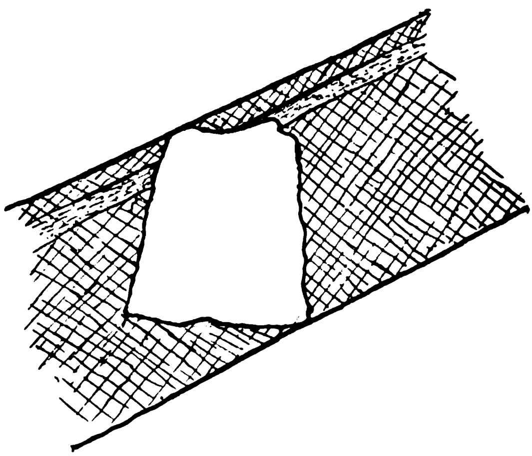
The Editor:

Sir.—Owing to absence I have but recently had the pleasure of reading the extremely valuable articles on "The Sampling and Estimation of Ore in a Mine." I trust this may serve as an excuse for the following rather belated suggestions:

In the consideration, on pages 39 to 41, of the much discussed question of "High Assays," the statement is made that "the occasional barren and the occasional high assay returns are not comparable in their effect upon the estimates." While this statement is true in the majority of cases, especially in the sampling of gold mines, it must be evident that the effect of the abnormally high or low assay would depend entirely upon the ratio which such assay has to the average. Thus, in the series of samples and assay returns, given on page 41, to demonstrate the above statement, if all three abnormal results, one very high and two very low, are omitted, the average becomes slightly less than 1.25 oz. per ton. The abnormally high assay, 27.4 oz., is 26.15 oz. higher, or approximately 2,100 per cent greater than the average, while in the case of the two low assays the total of the variation of both from the average is only 2.5 oz., or 200 per cent. Of course the effect of these assays upon the average is increased or decreased when the width covered by the sample is considered, but the above is sufficient to illustrate why such abnormal high assays "affect the estimates . . . to an extent by no means comparable to the omission of an equal number of poor results." That the occasion may arise wherein the elimination of a low assay would affect the result as much, or more, than the omission of a high assay is indicated by the following series based upon an examination of a silver lead property:

Property: Number.	Width.	Oz. Silver per ton.	Foot-Ounces.
1	5.3	57.4	304.22
2	4.9	39.2	192.08
3	4.6	53.1	244.26
4	4.0	59.6	238.40
5	4.0	101.3	405.20
6	4.2	54.9	230.58
7	4.9	42.8	209.72
8	4.7	1.4	6.58
9	4.5	38.2	171.90
Total	41.1		2,002.94

The average of the ore, using all of these results, is 48.7 oz. per ton. If No. 5 is omitted, this falls to 43.0 oz. per ton, while if the low assay is omitted, the result becomes 54.8 oz. per ton. None of these assays can be considered abnormal, nor is the effect of the elimination of either very large, with silver at 53c. per oz. In this particular instance, however, the effect was further emphasized by the fact that the sample containing 101.3 oz. silver per ton also assayed 63.0 per cent lead and 5.5 per cent. zinc, while the sample containing low silver contained 3.5 per cent lead and 11.4 zinc, the latter an especially objectionable feature.



In Mr. Argall's letter in the issue of June 13, Fig. 2, he shows what he truthfully states to be "one of the most difficult samples to take." When the vein assumes a flatter dip, as in the accompanying figure, it becomes practically impossible to secure a fair sample clear across the vein, and it is better to sample in sections, being careful to get a straight line across each section. I find it desirable to take samples very largely in sections if there is any difference in the parts of the vein which is clearly observable by the eye. In the examination of properties not equipped with treatment plants, where the metallurgical side of the question is necessarily an important one, results so obtained are of especially great assistance. Of course this increases costs.

The term "unequipped property" suggests another point, though perhaps it is beyond the pale of a discussion on the sampling of a mine. Mr. Denny remarks that when the engineer is called upon to decide whether a "prospect" is valuable or otherwise, and the available data are meagre, he is "forced to one or two alternatives, either (1) to intuitively sum up the value of the property; or (2) to refuse to commit himself to an opinion until more work is done." Now some of us who have not yet reached the *Ultima Thule* of being retained entirely by corporations which purchase only "going properties" are unfortunately, not infrequently, called upon by the man who, on the advice of "a friend who has seen it himself," has put money into a mine until he is tired and wishes to know what he has got. As Mr. Denny states, we are too judicious to adopt the first of the above alternatives, and Mr. Silkmerchant, who employs us, will not be satisfied with the second. It seems to me there is a third possibility, which perhaps, after all, is a combination of the other two. Why not state to Mr. S. that the present value of the property is only the small amount in cash which some development company would pay, advising from our experience what this might be, and admitting that from the information obtainable we can not express an opinion as to probable future value. Tell him it is "a gamble." By all means let us force upon the investing public, if possible, the difference between mining speculations and mining investments. Since, however, we estimate "possible ore" and "probable ore" may we not state definitely and succinctly, guardedly, the possible future value that might be expected from the expenditure of a stated sum in a certain definite development, which, so far as possible, is outlined in the report? To be sure, if this sum is expended and the property fails to come up to our guarded expressions of possibilities, we are liable to be blamed, especially by this class of clients; but, as Mr. Rickard has said "difficulty and doubt" have to be faced, and "judgment and experience must decide."

GEO. A. PACKARD.

Baker City, Ore., July 11, 1903.

The Editor:

Sir.—I have been much interested in the discussion of mine sampling, and hope you will continue to encourage such exchange of views upon practical subjects.

In some of the letters that you have published it seems that unnecessary refinement and care in doing the work are advocated. For instance, I confess I cannot see the necessity of having a canvas 20 ft. in length, to catch the pieces of ore while sample is being cut. It hardly seems advisable to cut such small samples as to render it necessary to catch every minute particle. With a piece of canvas 6 or 7 ft. long and as wide as the drift, using also, when convenient, a box or large Mexican *sombrero*, good sampling can be done. Again, it seems to involve unnecessary work and loss of time to seal up each sample as taken. It is assumed that the engineer has with him at least one man whom he can trust. Let him also take underground two sample bags, fitted with locks and keys—one bag for the originals and one for the duplicates. The samples can then be safely taken to the surface, there to be securely locked in a box or trunk until shipped or assayed. If the engineer is entirely alone, then sealing, as well as all other imaginable precautions, is necessary; but it is assumed that he will not alone attempt a job of any importance.

It is the custom of some engineers to have the samples (weighing perhaps 25 lb. each) packed out to the surface, to be "bucked" and quartered down. This is a slow and expensive method, unless the mine is supplied with a small crusher, and even then it is better to do a part of the "bucking" and quartering underground. The engineer should have two or three careful, honest assistants, to watch and quarter samples; two good, intelligent, reliable miners, to cut the samples; one man to help in quartering and tying, and three or four to do the bucking down. Such a gang can do good and fast work, and can carry all the tools and appliances necessary for the entire operation of cutting, bucking, and quartering underground.

I give below a leaf from my sample book, which is self-explanatory. It is well to have exactly 50 of such leaves in each book, bound in pasteboard. These books possess the following advantages: tags can be numbered before going down in the mine, and numbers checked; when duplicates of each sample are kept, tags can easily be torn in two; complete notes of each sample can quickly be made as sample is cut; results of assays can be recorded under head of "Remarks," on the back of the leaf; notes are in convenient shape for future reference.

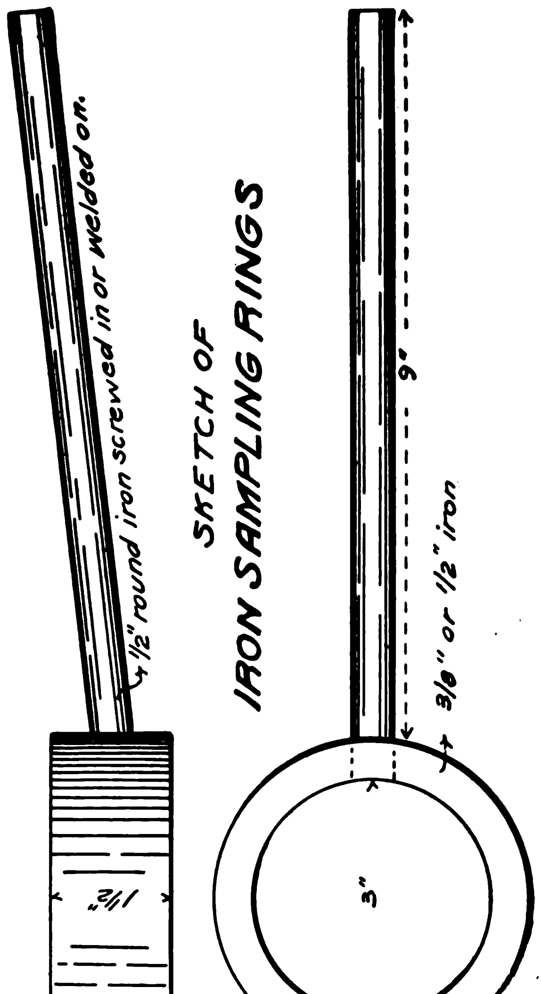
Sample Taken..................................
At point...
From ....
Across ....
For................. Feet ....Inches.
Measurement: Right Angle to Dip—Vertical or Horizontal.
To ....
Dip ....Strike ....
No ....

(OVER)

...............(Perforation here)...............
No.........................

No......................

SAMPLING CARD.


SKETCH OF
IRON SAMPLING RINGS
1/2" round iron screwed in or welded on.
1 1/2"
9"
3/8" or 1/2" iron
3"
1/2"

I also include a sketch of an iron ring and handle. Several of such rings add very little to the weight of one's luggage. When used in conjunction with 4-lb. hammers and large flat rocks or old stamp-dies, these rings enable the breaking of the ore (when reducing the bulk of the sample) to be done very quickly and thoroughly, and, at the same time, prevent pieces of ore from flying off the canvas and fingers from being smashed. Sometimes it is convenient to pack along a small hand-power jaw-crusher, but even then these rings will be found useful for the rough part of the crushing.

Leather sample-bags, two by two by one-half foot in size, made and looking like mail bags, with leather strap-handle on each end, are very useful. When filled with samples, two such bags make a proper and convenient load for a pack mule. Small pieces of tightly woven cloth are preferable to sample sacks, because suitable cloth may be obtained cheaply almost anywhere, and the sample can be poured onto a cloth more easily than into a small sample sack. It is well to mark the number of the sample on the outside of each cloth with an indelible pencil, at the time the sample is tied up. For quartering, oil-cloth is better than canvas or muslin, because it prevents the fines from sifting through and being lost during the process of rolling the samples. For soft and moderately hard ore, a well-balanced poll-pick, made of good steel, is the best tool for cutting the samples; for hard ore, moils should be used—for very hard ore, more moils. The poll-picks should be made of good drill steel, and should be provided with strong but springy handles.

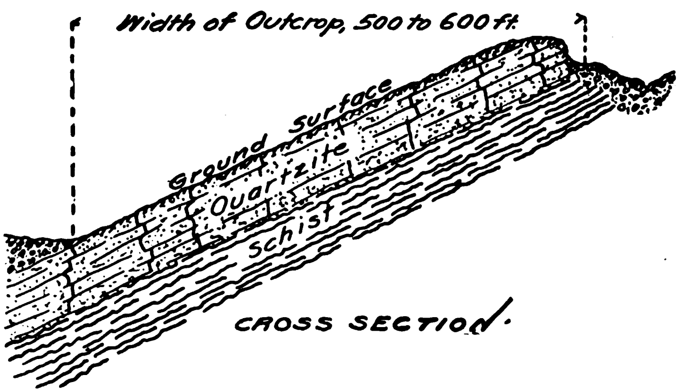
It is the belief of the writer that the results of mine sampling should be considered as only close approximations to the average values of the ores exposed, and that it is hardly worth while to take the trouble of making fine-haired calculations, to obtain average values. If proper care is used with regard to abnormal assays, the usual method of "foot-ounces" or "foot-dollars" gives results as close as are practical.

It is well enough to talk and write about taking a sample that truly represents the value of the ore, but doing it is another matter. If the ore for the full width of the section cut is more or less uniform as to hardness, and is not crumbly, a good sample can be obtained; but if it is decomposed, porous and crumbly, no amount of care will enable one to cut a true sample. In such cases it is well to take very large samples; and, in a general way, it may be said that there is greater safety, not only in large samples, but also in large numbers of them. If the ore varies greatly as to hardness, the hard or soft parts occurring in spots or bunches scattered promiscuously throughout the vein, it is difficult to do accurate sampling. If the hard or soft ore occurs in streaks, the difficulty may be obviated by sampling the streaks separately. Sometimes the only practical method is to do the sampling as carefully as possible, realizing that it does not truly represent the ore values, and then, after thorough study of the subject, apply a percentage correction to the average value thus obtained, as in the four following cases:

Case I.—Large bodies of low-grade gold ore, in which it was suspected that the soft ore was better than the hard; ore-bodies thoroughly prospected in the upper levels, and about 700,000 tons developed before milling was begun; ore-bodies carefully determined by samples taken 10 ft. apart and assays accurately platted upon maps; successful development of ore was continued after the mill was started; as a general rule, ore decreased in value with depth. After 140,000 tons had been milled, a second examination of the mine was made; new ore-reserves were sampled, and what remained of the old ones were resampled. Resampling of old-bodies gave practically the same results as first sampling. By use of the assay-maps, stope-maps, and records, a close comparison could be made between the mine sampling of the 140,000 tons, and the results from milling it, and it was found that the mine samples should have been discounted 14 2-3 per cent. This rate of discount was applied in calculating the average value of the large tonnage yet remaining, and with good results, as was afterward proved in the milling of it.

Case II.—Enormous body of very low-grade copper ore, occurring in form of small grains of chalcocite; could be determined easily by the eye that the soft parts of the ore were leaner than the hard; adits were driven into the ore-body, and samples were taken every 5 ft., alternating from side to side, so that samples were 10 ft. apart on each side; a separate mill-test was made on the ore from each adit; thus it was possible to compare the average of the mine samples with the average value of the ore as milled. Varying results were obtained in the different adits; in those where bunches of soft ore were scattered promiscuously throughout the harder ore, it was found necessary to add as much as 15 per cent to the average values shown by the mine samples, to make them correspond with the mill-tests.

Case III.—The property was represented as being a large body of low-grade, free-milling gold ore, having a width of 500 to 600 ft. The only workings were two open-



cuts and two shallow shafts. The deposit had a width of outcrop of 500 to 600 ft., but a careful examination showed that its actual thickness, while great, was only 50 to 60 ft. The accompanying sketch shows how the mistake in estimating the width occurred. The ore-deposit was in quartzite, containing here and there small, irregular seams of quartz. It was observed that the quartzite itself carried values, although values were higher in the quartz veinlets. The gold was finely divided, and only rarely visible to the naked eye. In 'bucking' the samples, for the purpose of quartering down, once in a while a few pieces of rock would be found showing comparatively coarse gold, and such pieces were rejected as a matter of safety. The ore was sampled in 10-ft. sections across the deposit, 269 samples being taken. These samples were 'bucked' and quartered down by hand in the usual manner, except that, before the last quartering, they were put through a small hand-crusher and reduced to pieces that would all pass 1/4-in. mesh. Samples were taken and assayed in duplicate, and the average value was $3 per ton. The price asked was a very large one, and as the deposit did not give much promise of going down, the proposition was rejected. Later it was bought for about one-fifteenth of the price first asked; a mill was built, and the ore was mined by the open-cut system. The writer was afterward reliably informed by the manager of the mine that the ore as mined averaged about $3.75 per ton.

Case IV.—In this case the ore-bodies were irregular ones in limestone, carrying gold, silver and lead. The mother lode of the district is a contact between diorite and Cretaceous limestone. The ore occurs in a system of three veins, situated at a distance of 1,500 to 1,800 ft. away from the main contact. They are parallel fissure-veins in limestone, usually conformable to the strike and dip of the stratification. The pay-ore is easily detected by the eye, and in mining great care is used to keep it clean. There was not much ore 'in sight' in the mine, but in the lower workings it had been mined in such a way that there was an opportunity to check the hand-sampling of the faces against the smelter returns on product for eight months. This check gave the following results: Lead, as determined by hand-samples, practically the same percentage as was shown by the smelter returns; silver values, from hand-samples, 13 per cent greater than from smelter returns; gold-values, from hand-samples, 36 per cent less than from smelter returns. Notwithstanding these differences in the silver and gold values, it was decided to rely upon the results of assays of hand-samples, for the following reasons: The sampling, as well as old smelter returns, showed that the ore was increasing in silver and decreasing in gold values, with depth; on the dump were several thousand tons of ore that had been mined during the two years previous to the eight months checked, which had not been shipped on account of lack of cheap transport facilities; this old ore carried about the same value in lead, but was lower in silver and higher in gold than the ore mined during the eight months' period. This latter ore had been piled up against the old ore, and in sacking it for shipment some of the old ore became mixed with it, so that about one-fourth of the ore sold to the smelters during the eight months was old ore.

One point that I do not remember having seen emphasized in this discussion is: The ore should be sampled in the same manner as it is to be mined.* This is especially true in Mexico, where labor is cheap and where Mexican miners are very clever at mining small streaks and assorting ore. The "plodding sampler," fresh from the States, with no experience in Mexico, might go through the workings in an irregular lead deposit in limestone, taking his cold-blooded samples at regular measured intervals, and then easily turn the property down as being of no value; while, afterward, by using Mexican methods, modified somewhat, perhaps, by American intelligence and skill, the mine might be made to pay thousands of dollars.

Another practical point, that might have been covered to advantage by the many engineers of wide experience who have contributed to this discussion, is this: In calculating ore-reserves, what allowances are to be made on

*This point was considered in the original discussion of the subject; see page 44 of this volume.

account of "horses" included within ore-bodies? Naturally, the percentage to be deducted varies widely with different veins or deposits, but results in some cases from actual experience might be of help in others. The following is contributed as one case:

Conditions: Large bodies of low-grade ore in an altered limestone, thoroughly developed; samples carefully taken 10 ft. apart; limits and thicknesses of ore-bodies determined by the extensive development and sampling; average specific gravity determined by a number of tests; stope-maps and records during mining kept in such a manner that comparison could be made between tons calculated and tons actually mined; about 450,000 tons mined by caving system; estimated loss due to caving system, not over 3 per cent. *Result*: Many lime "horses" found within supposedly solid bodies of ore, and tonnage mined was 20 per cent less than tonnage calculated.

R. C. GEMMELL.

Avalos, Zacatecas, Mexico, Sept. 22, 1903.

The Editor:

Sir.—In reading reports on mining properties, I find a tendency, when it comes to the calculation of the value of the ore and the profits in treatment, to mix up, unnecessarily, assays as expressed in percentages, ounces, pennyweights or grams, with values and costs, as expressed in dollars, pounds, francs or pesos.

I recently examined a report on a silver mine in Mexico, in which the assay maps purported to give the value of the ore in United States currency. The assays had been made in grams per metric ton of 1,000 kg.; this had been combined with the value of silver taken at $35, Mexican, per kilogram, and then exchange had been taken at 237. The mint value of a kilogram of silver is actually $40.914, Mexican currency, and the figure $35 only represented the allowance from a particular smelter on that particular ore, the difference being supposed to cover metallurgical losses and bullion taxes. Exchange is constantly fluctuating and, as nearly all expenses of mining are based on Mexican currency, the profit fluctuated with the rate of exchange. When it came to determining the comparative advantages of lixiviation and smelting, all the values in the maps had to be calculated back to grams per metric ton. Had the maps shown this in the beginning, all this trouble would have been saved. Nor should these assays have been reported in ounces troy per ton of 2,000 lb. avoirdupois. It is always well in a foreign country to figure and, if possible, think in the standards of the country, and not make a conversion till the very last item is reached—the net profit per annum, when the amount may be expressed in the currency of the country where the report goes.

It is a very common error in case of a copper or a lead ore to express the value in dollars by multiplying the value of the metal per pound by the number of pounds of metal shown in the ore by assay; then at some period in the chain of calculation to subtract a certain sum of money to represent metallurgical losses. When the ore has to be both concentrated and smelted, most unintelligible figures result and errors unwittingly creep in, or can be introduced by designing individuals. The only safe and logical way is to separate the metallurgical and commercial calculations into two operations.

As an example, I give a hypothetical sulphide copper ore carrying gold and silver, which is first hand-picked and the balance subjected to water concentration, to remove an excess of silica. The concentrates are divided into two classes, fines and coarse; the fines are roasted and then smelted in reverberatory furnaces, and the coarse concentrates, together with the hand-sorted ore, are smelted in blast-furnaces. The resulting matte is bessemerized and shipped to the Atlantic coast for electrolytic refining. This is an extreme case, but shows the method of calculation, which would be simpler in case the operations were fewer.

We will assume the treatment of 1,000 tons per day assaying 4 per cent copper, 4 oz. silver and 0.04 oz. gold per ton of 2,000 lb. avoirdupois. The metallurgical table follows:

Tons.	Material.	Assay. per cent Cu.	Contents. lb. copper.	Assay. oz. Ag.	Contents. oz. silver.	Assay. oz. Au.	Contents oz. gold.
1,000	Crude ore...........	4	80,000	4	4,000	0.040	40
100	Selected ore	10	20,000	10	1,000	0.100	10
900	Concentrating ore	3.00	60,000	3.33	3,000	0.033	30
450	Tailings (a)	1.67	15,000	1.67	750	0.017	7.5
450	Concentrates	5	45,000	5	2,250	0.050	22.5
200	Coarse concentrates ..	5	20,000	5	1,000	0.050	10
100	Selected ore	10	20,000	10	1,000	0.100	10
300	B. F. charge.........		40,000		2,000		20
400	B. F. slag...........	0.40	3,200	0.20	80		20
33.46	Matte	55	36,800	54.40	1,820	0.600	20
250	Fine concentrates.. .	5	25,000	5	1,250	0.050	12.5
50	Roasting loss (b).....		750		38		
200	Calcines	6.06	24,250	5.56	1,212	0.063	12.5
200	R. F. slag............	0.70	2,800	0.30	60		12.5
23.83	Matte	45	21,450	48.34	1,152	0.524	12.5
57.29	Matte		58,250		2,972		32.5
	Converting loss (c)...		1,165		149		
29	Pig copper	98.42	57,085	97.34	2,823	1.121	32.5
	Toll deductions (d)..		754		141		
	Refined copper		56,331				
	Fine silver				2,682		
	Fine gold						32.5
	Total loss		23,669		1,318		7.5

(a) Concentration by water, 2 into 1, with 25 per cent loss in values.
(b) Roasting loss, 20 per cent in weight, 3 per cent of copper and silver.
(c) Converting loss, 2 per cent copper, 5 per cent silver.
(d) Toll deductions for electrolytic refining, 1.3 per cent off electrolytic assay of pig copper and 5 per cent off silver assay. Gold all allowed for at $30 per oz. troy.

Coming, now, to the commercial side of the problem, we have the following table, showing returns and expenditures:

RETURNS.

56,331	lb. copper, at 13c. per lb........................	$7,323.03
2,682	oz. silver, at 55c. per oz.........................	1,475.10
32.5	oz. gold, at $20 per oz........................	650.00
Total	....	$9,448.13

EXPENSES.

Mining 1,000 tons ore, at $1.50 per ton	$1,500.00
Transport 1,000 tons ore, at 25c. per ton	250.00
Administration 1,000 tons ore, at 15c. per ton	150.00
Concentrating 900 tons ore, at 35c. per ton	315.00
Roasting 250 tons concentrates, at 30c. per ton	75.00
B. F. smelting 300 tons ore and conc., at $2 per ton	600.00
R. F. smelting 200 tons calcines, at $2.50 per ton	500.00
Converting 57,085 lb. copper, at .006c. per lb	342.51
Freight, 29 tons copper, at $12 per ton	348.00
Refining 29 tons copper, at $16 per ton	464.00
Comm., etc., 56,331 lb. copper, at .005c. per ton	281.66
Total	$4,826.17
Gross profit	$4,621.96

From the above figures the annual net profit can be deduced after allowing for a fixed annual amount to cover construction, depreciation, etc.

I must disclaim any intention of giving the above figures of cost as representative, though there are places in the West where the conditions as to cost might obtain. My idea is simply to give a form for calculation where losses and costs are not mixed.

J. PARKE CHANNING.

New York, Dec. 14, 1903.

The Editor:

Sir.—As illustrating that mine sampling, already sufficiently tedious and exacting, can be extended until it becomes a sampling of a sampling, I venture to contribute the following notes, made in the course of practical work and recent mine examination experience; also thinking that the item may be suggestive without having claim to any great originality.

This note refers to the sampling of the 'quarterings' of a definite number of samples, as convenience dictates, for subsequent comparison of the resulting assay of this special sample with the average assay results of the particular samples included in the former.

The necessity for such practice as I am about to describe suggested itself to me in an instance where I was making an examination, and had to limit myself to one assistant, under circumstances which demanded more than usual precaution in the care to be exercised in the sampling, as well as in the safeguarding of the samples taken.

A pre-requisite to the carrying out of this scheme of sampling check is that the sampling-cut shall be made of a regular width, so that the wider vein shall be represented in its due proportion, as also the narrower (and generally higher grade) streak in its proportion.

The sampling described herein was more extensive than the sampling numbers indicate, but the part of it published will, I think, sufficiently illustrate the idea which it is wished to convey. The quartering or reducing of the samples was done in the mine as sampling progressed; the calculation of averages is based on the geometric mean or "foot-dollar" method. The detail of the sampling compares with the result of special samples as follows:

No.	Vein width, ft.	Assay value.	
11	4	$3.60	Special sample of quarterings of Samples 11 to 16, inclusive, $2.70.
12	5.5	5.00	
13	2	5.00	
14	3.5	0.60	
15	5	3.60	
16	3	1.20	
	3 5/6 ft. av.	$4.10	
20	4.5	$3.20	Special sample of quarterings of Samples 20 to 23, inclusive, $3.20.
21	6.5	2.60	
22	5.5	8.00	
23	5.5	3.20	
	5 1/3 ft. av.	$4.13	
26	5.5	$3.60	Special sample of quarterings of Samples 26 to 32, inclusive, $1.50.
27	7	1.80	
28	6	3.20	
29	6	1.80	
30	5.5	4.00	
32	6	*18.00	
	6 ft. av .	$2.70	

42	2.5	$8.00	Special sample of quarterings of Samples 42 to 49, inclusive, $1.60.
43	3.5	6.80	
44	3	0.40	
45	3	2.40	
46	3	2.20	
47	3.50	1.60	
48	3	0.60	
49	5	0.40	
	3 1/3 ft. av.	$2.60	
51	3	$4.80	Special sample of quarterings of Samples 51 to 54, inclusive, $3.10.
52	4	6.80	
53	4	1.40	
54	3	1.40	
	3.5 ft. av.	$3.67	

*Eliminated sample No. 22 as "spotty" and substituted average value.

The care taken in preparing these samples and the accuracy of the assaying is indicated by the uniformly close result of the control assay, which was taken to a public assayer of good repute. Thus:

Special sample.	Original, oz. gold per ton.	Control assay, oz. gold per ton.
11 to 16	0.14	0.13
20 to 23	0.16	0.16
26 to 32	0.08	0.07
42 to 49	0.08	0.08
51 to 54	0.18	0.13

While this particular ore happens to be a low-grade ore, it might be interesting to carry out a similar test on ores of higher grade and different character.

It will be noticed that the special sample of the 26 to 32 series catches the irregularity occurring in No. 32 sample, and proves that the nature of this discrepancy was in the assay rather than in the sample itself.

Another thing, the result of the quarterings sample is, in every case, appreciably lower than that of the average of the equivalent sample series. As these samples were all of them quite dry when quartered down, this latter observation rather indicates that the fines which cling to canvas to some extent (and almost unavoidably) tend to carry higher values than the coarser material. This property of canvas has been remarked in other papers on the subject of sampling; and it is my observation that the extent to which the fine residuum or dust that clings to canvas, and with it, sometimes, particles of very fine metallic gold, can be approximately determined in almost any case. This can be done by the simple resort of taking, and repeatedly taking, about an even bulk (relative to samples) of absolute waste material, and reducing this and quartering it down in the same way as the regular samples of the mine. In addition to the special samples, I took precaution to include among my samples a number of waste samples. Such samples constitute not only a check on the sampling, but on the assayer, and bring to light any irregularities that might possibly creep into the most careful sampling. I am inclined to think that there is much more said about the inclusion of waste samples than is actually carried into practice.

While the extra trouble of sampling the discarded portions of regular mine sample may not always be warranted, nor oftentimes be deemed necessary, it certainly gives additional data upon which to depend for information of general values, and under some circumstances it more than compensates for the trouble that it involves.

FORBES RICKARD.

Denver, Colo., Dec. 1, 1903.

REVIEW OF DISCUSSION.

By T. A. Rickard.

In closing the discussion on mine sampling, I desire to thank those who have contributed their comment and experience. Whatever service my treatment of the subject may have done, it has been much increased by the discussion.

The efforts to give precision to the terms used in describing the ore opened up by mining operations will, I doubt not, leave their influence on the practice of the profession. Already "ore in sight" is tabooed and "ore developed" has appeared in several reports upon mines. Mr. Argall has driven the last nail in the coffin of a phrase which was previously almost *in extremis* by reason of the action of the Institution of Mining and Metallurgy, whose circular (published in the Engineering and Mining Journal of October 18, 1902) made a distinct pronouncement concerning the careless use of such terms. In endeavoring to supply a definition the council of the Institution did a good service to engineering practice, but ventured upon dangerous ground. No set terms can always cover the relative degree of evidence to be obtained concerning the tonnage of ore available in different mines. Each mine has its own "personal equation," as it were; in each instance there is a degree of regularity, or irregularity as it may be, of ore occurrence, both as regards value and width, so that two sides of a block as exposed in one class of mine possessing persistent ore-shoots affords better assurance of a certain amount of ore in reserve than four sides in other mines where the vein is sporadic and fickle. This point has been brought out by

Messrs. Geo. E. Collins, Chester W. Purington and John C. Treadwell.[1]

This aspect of the enquiry is also emphasized by the consideration of unsystematic sampling, as outlined by Mr. Geo. J. Bancroft.[2] The writer happens to know the two engineers whose methods are adumbrated by Mr. Bancroft, and he can appreciate that men of such wide experience are able, by the exercise of sagacity, to make one or two, apparently haphazard, tests which will throw more light on the character of a mine than the laborious sampling of an inexperienced man. Short cuts are proverbially dangerous to the novice, while they may be safe to a veteran. There is no doubt that clients who have to pay heavily for the detailed sampling of a large mine will appreciate the acumen of an engineer who by a few tests, judiciously distributed, can, at a small expense, find out the real inwardness of things. This applies particularly to preliminary examinations.

The shape of ore-bodies is an important factor, as Mr. Purington makes clear.[3] One cannot sample intelligently, that is, one cannot arrive at the size and average composition of a large mass of any material unless one has some notion of the shape of it. Here geological structure plays an important part, as it has been my endeavor to show in the two or three instances which I have described. The instances have been invariably founded on fact and described with care, so that many readers must have been able to spot the localities from which they were borrowed.

That sampling is hard work, as well as an important part of mining practice, is a fact scarcely needing emphasis to professional men, but I doubt if it is, as yet, properly appreciated by the people in whose interests it is done. Therefore the detailed description of the sampling of the bottom of a wet level by Mr. Ernest Levy will do good service.[4] Moreover, it suggests the extreme care required

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[1]See pages 93, 96 and 115.
[2]Page 118.
[3]See page 96.
[4]See page 124.

to sample underfoot, especially in a wet mine. As a rule, if sufficient data are otherwise procurable, it is best to leave the bottoms of levels alone, because of the great danger of vitiated results due to the washing of fine ore into the channeling made by the moil or pick; moreover, it is rarely possible to be sure that the proper width of ore is being broken when working in the bottom of a drift. The necessity to tear up the track, stop the tramming and interfere with the operations in any part of the mine causes the management to look with disfavor upon the sampling of bottoms and leads usually to the work being done in a hurry, under great discomfort and under serious disadvantage. These tend to impair the reliability of the results. Therefore, if practicable, sample the backs over the level or the nearest winzes in preference. If these are not available, that is, if the ground above the level is stoped out and the ground underfoot has not been penetrated by winzes, then sample underfoot and make up your mind not to be rushed, to do it carefully and to have the operation conducted under your immediate supervision.

Mr. Chester F. Lee asks[5] whether it is admissible to combine several cuts across the vein at short intervals or to take separate samples at greater intervals? To this I would say that the mixing of samples obscures the information which they can give and spreads the element of error. If one is limited, by time or money, in the number of samples to be taken, I would prefer, for example, one hundred separate cuts at intervals of ten feet to the same number of samples obtained by combining every two cuts taken at intervals of five feet. If a bad sample is taken, either by encountering an accidental rich spot or by breaking an undue proportion of one part of the cross-section of the vein, then by mixing this with the next cut, the error is only made so much more difficult of detection. Moreover, such sampling by requiring twice the number of cuts, without any increase of precision, unnecessarily

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[5]See page 129; also Mr. Gemmell's remarks on page 184.

augments the time and labor involved. Each assay result and each width represents a factor in the final calculations for tonnage and value; the more of these there are the closer the estimate. But by combining two adjacent cuts there is no increase in the number of assay results, although there may be double the number of measurements for width. In an erratic ore-streak the latter would prove useful.

Mr. T. Lane Carter and Mr. G. A. Denny have enriched the discussion by their descriptions of South African practice.[6] Nowhere in the world is sampling so nearly an exact science as in the mines of the Transvaal, simply because these contain ore-deposits of such persistence and uniformity that they afford the basis for careful work. The stuff is there, and it is not so erratic in occurrence or in richness as to upset calculations founded upon the doctrine of averages. After all, the value of any system must depend upon the comparative regularity of conditions assumed to exist by the mere fact of a regularity of method. Stereotyped procedure is stultified by the want of some measure of uniformity. For these reasons, the engineers on the Rand have had a great opportunity to improve sampling methods. This they have abundantly done. One of the best systems is the scheme of a continuous section-plan, proposed by Mr. F. Burnham,* which has been adopted by several mines, and is described by Mr. Denny. By indicating the average assay of separate lengths of reef by means of tints upon the mine map, it is possible to get, at a glance, the relative value of the workings; the unit is a full stoping width, so that the tints mean *not* the gold contents per ton of any streak or vein, but the value *as stoped*—a very different thing. This continuous section-plan is of great service to the management of a large mine. When supplemented by the sampling record, which contains a continuous sketch of the distribution of the pay-streaks in a wide vein, as shown in

[6]See pages 131 and 163.

*'Continuous Section System Mine Sampling,' by M. H. Burnham, *Transactions* Institution of Mining and Metallurgy, Vol. X, pp. 204-218.

the section-plan, this system affords, in a compact and logical manner, a great deal of the vital information necessary to good management.

Mr. Denny pleads for a minimum of 5 ft. as the sampling interval, and quotes differences observed when a longer interval has been adopted. It is obvious that the shorter the interval the more accurate the averages obtained, for every interval represents a column of ore having the length of the interval, the width of the ore, and the height of the block. The last dimension is shared, usually, with a corresponding sample on the next level. In practice the interval is usually determined by the exigencies of time and expense. When a mine is well organized and has men who are told off to attend regularly to the sampling of the workings, it is practicable to reduce the interval and do the work up to the extreme of detail; when, on the contrary, an engineer is sampling a mine preparatory to submitting a report upon it, he is apt to be limited by time and by the funds placed at his disposal by his client; as a consequence, he cannot spend all summer on one examination. It depends as much upon the client as the engineer; the better class of the former will not hurry the work and will not stint the expenditure necessary to do it well. One can only say that the engineer cannot be too careful, and to that end he will endeavor to find time and money sufficient to take samples at the shortest interval required by the nature of the lode. In one mine, quoted by me, I sampled every three feet, and even then the interval was short enough, seeing that the vein averaged 4 inches of ore carrying 500 oz. of silver per ton; in other cases, of uniform low-grade pyritic lodes, a 20-ft. interval would give closer results than the 3-ft. interval in the case just referred to.

Mr. Denny pleads for the general expression of values in terms of currency. This is a good point. Ounces of gold mean bullion of uncertain value; ounces of silver, percentages of copper, lead, etc., vary in value with changes in the market. Mining is a matter of money. I remember hearing of the case of an engineer who examined an Indian mine in the early days of the Wynaad, and instead of using the assay-ton he employed the old-fashioned percentage method, with the result that he misplaced the decimal point! A colossal blunder followed. If he had used currency instead of percentages as his unit, he would not have made such a fatal slip. Furthermore, mining operations nowadays cover regions of such diversity that the bullion contents may range from a 50 per cent alloy to gold of 995 fineness. To report in quantity of bullion is only to afford one more chance of misunderstanding, and, after all, the purpose of all engineering work is to get at the facts and then to state them beyond the peradventure of misconception.

Mr. T. Lane Carter describes[7] current practice on the Rand and the arrangements made by the mine management for the regular sampling of the workings. It is plain that at Johannesburg the sampler has won a distinct position for himself. Incidentally he accentuates the usefulness of correct assay-plans as indicating the value of any portion of the reef which is too poor to be worked now, but may be found profitable under more favorable economic conditions. When that time comes, an accurate record of the values as determined by the previous daily sampling of the drifts will be found of great service. The use of surveyor's points to locate the places sampled is a good scheme, since other points of departure may become obscured. Furthermore, it suggests the friendly relations which should exist with the surveyor's department; in fact, it would be well in most mines to put the sampling work, and the records of it, under the charge of the surveyor attached to the property.

Mine sampling on the Rand has been developed to the dignity of a distinct branch of practice; therefore, Mr. Denny's description of the methods in vogue is most opportune. His criticism[8] in regard to the ascertainment of the "average value of the ore in the past" from "the records of a mine" is due to a misconception of my meaning.

[7]Pages 131 to 138.
[8]On page 166.

I meant the value per ton, as treated in the mill or smelter, of the ore produced in the past, and not the average yield of the ground which has been removed by stoping. I quite agree with Mr. Denny that it is difficult to arrive at the yield per fathom, or per square foot, of lode in workings which have been abandoned; and, of course, we are well aware that many a false notion of the grade of lode-contents has arisen from a literal acceptation of the story told by mill and smelter records. On the other hand, if the examination of a mine extends over several months, it is occasionally possible to check sampling results by measuring a block of ground and then getting the actual yield of it in tons of ore and in ounces of bullion. There are also instances where the management of a mine is in honest hands—for all sellers of mines are not dishonest, nor are all buyers immaculate—and then it may happen that the stope-maps have been kept in such a way that the yield per fathom, the average width of clean ore as compared to the stoping width, the percentage of sorting, and other data, can be secured and utilized as a check on the estimates based on sampling alone.

Mr. J. H. Curle taps the milk in the cocoanut in his contribution on mine valuation.[9] It is the net profit that an engineer is asked to determine; all the rest is noise and smoke; tonnage of ore, assays, machinery, water power, timber rights, dump facilities, scenery—all these are mere frills on the outside of the essential problem, How much money will the mine yield? This is being recognized more and more; twenty years ago it was customary to make a perfunctory trip through the underground workings, to break off a specimen or two, and then to spend a few days copying the past records of production, getting tracings of the maps and interviewing the oldest inhabitants. With such data, it is no wonder that mine reports became a thing for derision. It is just such plain talk, straight from the shoulder, as this of Mr. Curle's, which goes to the heart of the problem and brings the thoughtful

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[9]See pages 138 to 145.

engineer into touch with the financial side of a great industry; it means the passing of the professor type and the development of the experienced engineer, who knows human nature and the brutalities of the financial arena no less than the contents of text-books and the talk of the library.

There is no doubt that Mr. Curle is right in saying that the environment of the English engineer is against him in this respect. In America the engineer deals directly with a capitalist who usually knows a bit about the business of mining, but in London he is apt to run against a wholly impossible type, the middleman, to whom the mine is merely the basis for clever dealing, or the titled incompetent who is in the hands of the former and plays a part like that of the Indian whose wooden image stands in front of the cigar store.

Mr. Curle speaks of a mine valuer taking certain risks in figuring out the ore reserves; it is not in the estimates of ore blocked out that the chances of error are so great as in appraising the future prospects, the "good-will," as it were, of the property, that the largest margin for difference will occur. Mines are not bought only for the ore actually calculable in the existing workings, but also with the idea of a future enhancement in value due to intelligent development. Here it is where a man must be true to himself and to his employers, by facing the facts frankly; and if the facts are insufficient to warrant a forecast, let him dig them out by further investigation. If they are not available after thorough examination of all the circumstances, then let the engineer say so frankly, to the end that his client may know just what risk he is taking; in many cases a risk may be warranted, in others the condition of the mine and its past history may render it out of the question.

Mr. Argall emphasizes[10] the necessity for taking samples of approximately equal weight; this is important. Of course, the samples will vary in bulk with the width of the lode; the amount broken should be equal per foot of cross-

[10]On page 103.

section. When you leave it to such accidental factors as hardness and accessibility to fix the size of the sample, you simply introduce an unnecessary element of error, because excess of ore broken means usually that it comes from a soft part of the lode, while a meager sample will coincide with extra hardness. In most lodes the difference in ease of fracture is due to some constituent mineral, the presence of which is likely to coincide with a variation in the value of the ore.

It is good practice to brush the face clear of dust or remove any mud which is not in place, because this foreign material frequently contains finely powdered sulphides which may vitiate the sample, especially in a low-grade gold ore. Mr. Argall makes several other good suggestions, such as that of allowing two gangs of samplers to take alternate intervals in sampling, thereby checking each other's work.[11] As to the use of a hand rock-breaker, that is almost imperative where a big mine is being investigated; it will facilitate the careful quartering down of samples.

Both Mr. Curle and Mr. Argall discuss that much-mooted question: what to do with erratic high assays.[12] This was considered at some length in my own treatment of the subject;[13] but as a general method, to be departed from only where peculiar conditions arise, as in the cases described by Mr. Curle and by myself, I do not know of any better advice than that of Mr. Argall, that is, to reject the erratic results—and there will not be many of them, otherwise they are *not* erratic—and then insert the average values as given by the other results. In getting at this average it will be well, it seems to me, to omit those results which give *nil* and insert the figure given by averaging only the pay ore. This will lean a little to the idea, which is true, that these erratic assays do indicate unusually rich spots—but spots, not masses.

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[11]See page 105.

[12]See pages 111 and 142. Also Mr. Packard's remarks on low assays, given on page 181.

[13]On pages 39 to 44.

Thus, take the following list of actual assay returns from the sampling of a gold mine:

No. of Sample.	Width in feet.	——Gold value in dollars—— Original.	Duplicate.	Mean.	Foot-dollars.
1...........	7.0	$24.20	$48.00	$36.10	$252.70
2...........	4.0	10.80	8.00	9.40	37.60
3...........	12.0	24.00	23.20	23.60	283.20
4...........	8.0	84.00	78.00	81.00	648.00
5...........	5.3	740.00	496.00	618.00	3,275.40
6...........	7.0	32.00	40.00	36.00	252.00
7...........	3.5	19.20	64.00	41.60	145.60
8...........	6.0	8.00	8.40	8.20	49.20
9...........	6.0	24.40	64.00	44.20	265.20
10...........	7.0	28.00	16.00	22.00	154.00
11...........	7.3	9.60	40.00	24.80	181.04
12...........	8.0	230.00	392.00	311.00	2,488.00
13...........	3.3	30.40	45.60	38.00	125.40
14...........	9.8	6.60	15.20	10.90	106.82
15...........	8.5	1.20	6.00	3.60	30.60
16...........	9.2	13.40	11.20	12.30	113.16
17...........	10.5	5.00	11.20	8.10	85.05
18...........	10.0	7.20	17.60	12.40	124.00
19...........	6.7	17.00	19.40	18.20	121.94
20...........	11.4	4.00	5.00	4.50	51.30
21...........	4.6	3.60	4.40	4.00	18.40
22...........	10.0	15.40	9.20	12.30	123.00
23...........	5.0	21.60	30.20	25.90	129.50
24...........	10.7	20.00	17.00	18.50	197.95
25...........	8.4	16.00	12.80	14.40	120.96
26...........	8.0	31.20	20.80	26.00	208.00
27...........	9.0	13.20	20.40	16.80	151.20
28...........	6.4	6.80	7.60	7.20	46.08
29...........	6.2	13.60	16.00	14.80	91.76
30...........	8.0	6.00	6.40	6.20	49.60
31...........	9.9	20.00	8.60	14.30	141.57
Totals	236.7	$1,486.40	$1,562.20	$1,524.30	$10,068.23
Averages ...	7.6	47.95	50.39	49.17	

In the first place, the assays were made on two parts of the original sample, and not on the two halves of the final pulp; therefore the high results given by Nos. 5 and 12 indicate that there was this amount of gold present in the sample as a whole and not in a small portion of the pulp alone. The difference in the "original" and "duplicate" are due not to faulty assaying, but to the fact that the two halves of the sample actually differed in their contents. It is obvious that the division of the original sample into two, in this way, serves the purpose of testing the distribution of the values, and it is also a check on the high assays by indicating whether they are due merely to an accidental particle of gold in the assay pulp or really to a rich spot in the lode. If done by different assayers, this method is a check on the assaying itself. The arithmetical mean of the assays of the two halves differs, as will be seen, 4.8 per cent only; which, having regard to the character of the ore, a free gold quartz, is most satisfactory.

On the figures, as given, the ore averages 7.6 ft. in width and $42.53 (10068.23 divided by 236.7) in value per ton, which is about $6.50 less than the arithmetical mean of the assays. If, now, the two high assays are omitted, the average becomes $19.27 (that is, 10068.23 minus 5763.40, divided by 236.7 minus 13.3), which, having regard to the fact that rich spots are known to contribute an integral part of the output of the mine, is probably too small. If the engineer has the opportunity, he will resample the rich spots and also take intermediate samples between Nos. 4 and 5, 5 and 6, 11 and 12, 12 and 13—thereby finding out for certain whether the rich ore does occur to the extent of the 10 ft. in length, which in this case is the interval between the samples. In default of such re-sampling, as, for instance, if he has left the mine by the time he gets his assay returns, then he should substitute for 5 and 12 the average obtained by omitting the two high assays and also the very poor samples, such as Nos. 2, 8, 14, 15, 16, 17, 18, 20 21 22, 28 and 30. This will give an average of $27.70 for the richer ore as obtained by subtracting 5763.40 (3275.40 and 2488) from 10068.23, and also deducting 834.21 (the sum of the foot-dollars representing the 12 lowest assays), and then dividing by 126 (236.7 less 111.7, the aggregate width of the 14 samples omitted).

Now, substituting $27.70 in place of the two high assays and putting in the corresponding foot-dollars for Nos. 5 and 12 in the last column, we get a final average of $19.75 per ton, that is, 4673.24 (10068.23 minus 5763.40, but plus 368.41), divided by 236.7. This $19.75 compares with $49.17 without any correction and $19.27 when the two high assays only are omitted.

In most cases the result obtained in this way will be corroborated by actual mining and milling. In this case the difference made by taking the average of the better grade ore, instead of taking the average of *all* the other samples save the two "high assays," is comparatively slight, but the example quoted is intended chiefly as illustrating a method rather than a result.

Mention has been made, by Mr. Bancroft, for instance,[14] of the air of importance given to the supposed greater accuracy of mill-runs as compared to the assay of numerous small samples. This is a heritage from an older period. It is obvious that the bulk of a sample weighing several tons requires that it shall be handled by several men, and that this affords plenty of opportunity for tampering with the ore. Either the choice of the ore broken can be made so as to favor the desired result, or actual "salting" can be perpetrated with comparative ease. Furthermore, the number of ounces of amalgam scraped off the plates in a mill depends largely on the previous conditions of the plates, that is, the amount of gold amalgam which they carried when the test began. If rich ore follows poor ore in a mill, the plates get part of it, and the yield is too low, while if the reverse happens and poor stuff is milled after rich ore has passed over the plates, the result will be unduly high. In one case, which came under my notice, several lots of ore were broken in a certain mine and were sent to a custom chlorination works for treatment, with results which ranged between $12 and $17 per ton, but when the mine had been bought, on the evidence of these returns, it was found that the ore yielded about $8 per ton. Of course, in breaking the supposed "samples," no average was really secured because there was a general desire among all concerned, quite honestly, to get a satisfactory yield. As to the use of stamp-mills for such tests, it is obvious that there is great danger of both willful and innocent deception. From feeding amalgam into the mortar boxes to scraping the plates down to the bare copper, there is every modifica-

[14]On page 123.

tion. It is the old question of one big sample versus many small ones. However big the sample may be, you get one figure and one factor; with many results from a large number of samples you average the data, minimizing the errors and, often, detect them by the mere process of comparison.

The discussion has brought out many sides of the problem of mine valuation; what may be called the purely mechanical side, the sampling itself, obtained the first emphasis because it is fundamental to all the mental processes which result in the estimation of ore in reserve. Mr. F.H. Minard points out[15] that to delegate sampling to inexperienced youths is a dangerous procedure, because the carrying out of the work involves something more than ability and energy; the measuring of ore and breaking of samples requires experience, and if the preceding treatment of the subject has not made this abundantly clear, it has failed egregiously. Therefore engineers should not delegate their work indefinitely, nor, if they are wise, will the younger men court disaster by undertaking tasks for which they are unfitted. There is such a thing as learning one's profession; a man must be an apprentice before he becomes a master. And when all the sampling and investigation are done the great problem of valuation is there still, to try the mettle of the engineer. It takes a strong man to be a good valuer, says my friend Mr. Curle. It does, indeed—the kind of moral courage which faces facts and sends sophistry to the devil. It is the courage which animates science and refuses to make two and two anything but four, neither making it three by over-caution nor swelling it to five by an unhealthy optimism. The engineer whose estimate is 25 per cent below the fact is, in my opinion, as blameworthy as the one who makes it 25 per cent too high. It is well enough to say that you safeguard your client, if a buyer, by putting a low valuation on a mine, but there is no honesty in such a line of reasoning, for you are helping another man to get something for less than it is worth

[15]On page 176.

and giving the lie to your professional judgment. To overvalue a property, when caught by the enthusiasm of the seller, is foolish enough, and, as the world goes, it brings a speedy retribution by becoming destructive to reputation. But the two departures from fact are of a piece; there is nothing to choose between them; and to say that they are both equally unprofessional is as much a euphemism as it would be to say that it is unseemly to tell an untruth.

Every mine is a new and distinct problem; the valuation of it requires not only the determination of actual ore measurable, but the appraisal of future possibilities. There was a time when the gambling element was involved in the sampling, for it was rendered as haphazard as the throw of the dice; but since the thorough testing of mines has grown to become a recognized procedure, the judgment of prospective value looms up with added significance. Mines will not be bought and sold, in the future, like a cheese that has been tested; they will be taken over for the speculative enhancement to be secured by skillful development. As Mr. J. Parke Channing shows,[16] you can buy pyrites mines on the basis of a formula, in which certain determined factors are properly included; but when it comes to appraising the prospective enhancement of gold, copper and lead mines, for instance, formulas are thrown overboard, and there is need for that instinct, judgment, *nous*—call it what you will—which enables one miner to arrive at a safe guess, while the other sees no further than the head of his pick. It is the training of the "tributer" or "leaser" which is needed.

While the moil is the accepted tool for sampling, the gad is advocated by Mr. Lee and the small pick, but only for special work, by Mr. Walter H. Weed.[17] In certain places underground a gad, fitted with a handle, is more serviceable than a moil, that is, when the ore to be sampled is so situated that one cannot hold a moil in the left hand so as to strike it with the

[16]See pages 88 to 90.
[17]See pages 128 and 145.

hammer held in the right. The gad with a handle is one of the oldest implements of the miner, and figures in the insignia of the Schools of Mines at Leoben and Clausthal. As to the small pick, the geologist's or expert's pick, as it would be termed in the West, it is useful in preliminary sampling and in testing various parts of a vein to find out which streaks carry the values, but I am loath to recommend it for systematic sampling, especially in hard ground. It can be used by an experienced man with discretion to good purpose, but I would advise the younger engineers to leave it at home or in the blacksmith's shop. Much the same is true of the "grab" sample which I consigned to perdition as being at the root of so many untrustworthy estimates of ore. Mr. W. M. Courtis and Mr. Albion S. Howe say,[18] very properly, that the grab sample is serviceable in finding out which band of ore, in a multiple vein, carries the values, and in this way, by taking one or two grab samples, Mr. Courtis has saved himself, on more than one occasion, from being salted. Here, too, for a specific purpose, this method is well enough, but as a general way of arriving at the tonnage and value of large bodies of ore, it is hopelessly unscientific; in fact, the very notion of a "grab," that is, to seize blindly at a handful of broken ore, with the idea that by being blind you are impartial, is wholly opposed to the earnest effort to eliminate the element of chance as much as possible, by collecting the maximum number of data, and applying to them the doctrine of averages—which is the basis of systematic sampling.

In regard to the matter of rolling sticky ore on canvas or duck, as discussed by Messrs. Richard A. Parker, W.L. Austin and G. M. Gouyard,[19] any error due to this cause may arise from the fact that rich ore becomes powdered in the course of reduction, especially in the presence of pieces of 'gouge' or clay, such as frequently mark the walls of lodes. A sample of poor ore may become 'salted'

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[18] On pages 129 and 130.
[19] See pages 150, 151, 152.

if rolled on the canvas cloth which has been used in quartering a richer material. The discussion of this point serves to accentuate the dangers surrounding the quartering of samples; but while the use of canvas for this purpose is open to objections, it still remains the quickest way to accomplish the desired end—of reducing the bulk of the sample—in the absence of suitable split-shovels and other apparatus, which are not readily portable to distant mining localities. Wherever convenient, and especially in the case of the examination of important mines, I would advise the employment of a split-shovel and sampler, of the kind used in assay offices.[20]

In regard to the use of a strip of canvas to catch the ore as it is broken instead of using a candlebox, I cannot agree with Mr. Walter Harvey Weed,[21] because, even if intentional 'salting' be prevented by excluding everyone save those engaged in taking the samples, unintentional interference with correct results will arise from the falling of bits of ore outside of the range of the section sampled. In many lodes carrying friable minerals or pulverulent ore, or even sugar quartz, which has been loosened during the course of mining, there will be a tendency for particles to drop onto the canvas from spots not being sampled, owing to the vibration set up by the blows of the hammer on the moil. Rock at a distance will be jarred loose and will get mixed up with the sample being taken. Of course, if the candle-box is not held near the face of ore, the chips broken off by the sampler will fly wide and some of the material broken will escape the box, but this, with a little experience, can be obviated. The man holding the box can put his hand up to the face of ore so as to catch the broken rock and the candle-box can be held so as to arrest the flying chips. In any event, to my mind the use of a canvas is open to the objection mentioned, and should not be resorted to except in *one* contingency—that is, when an engineer is alone, has no assistant with him, and has reason to distrust any help

[20]See also page 25.
[21]See page 145 and also page 179.

which is offered by those on the mine. Under such circumstances he cannot very well take a large sample, without placing a canvas on the floor of the level or stope so as to catch the ore broken down by him, because it is physically impossible for him to hold a box and break a sample at the same time.

The remarks of Mr. George A. Packard[22] concerning low assays are much to the point. In ores containing metals in quantities large as compared to the minute proportion of gold usually present in lodes, there is a tendency for erratic low results to disturb the real average just as much as the "high assay" in gold mines. But, as pointed out already, the high result always differs from the low, especially in the case of the precious metals, because the former may be due to an accidental inclusion of a small particle of specimen ore or a "metallic' in the final pulp, while the latter simply bespeaks an absence of rich ore in the whole of the sample, provided the latter has been reduced so that the assay pulp represents the average contents of the crude ore broken in the process of sampling.

In regard to talking straight to one's client, telling him whether the facts are sufficient to be the basis of an opinion or not, explaining the element of risk and taking care to distinguish between probabilities and possibilities —in all this I agree heartily with the views expressed by Mr. Packard,[23] and, as the reader is aware, I have endeavored to emphasize the advisability of being outspoken, for business reasons, as well as from finer considerations.

The mathematical demonstrations and methods of calculation described by Mr. Blamey Stevens[24] and by Mr. Auguste Mathez[25] are interesting, not only because they will facilitate the arrival at conclusions, but chiefly from the fact that they illustrate the methematical basis for the methods which men reach more laboriously through ex-

[22]On page 181.
[23]See page 183.
[24]On pages 155 to 161.
[25]On pages 161 to 163.

perience. Empiricism, rule of thumb, practical ways—these are all reached by a process of elimination, and, in so far as they are logical and survive the test of usage, they can be expressed in terms of mathematics.

Mr. Gemmell offers several useful hints.[26] In deprecating "unnecessary refinement" of method he exhibits a natural impatience, for once a man is thoroughly experienced he can dispense with certain details of procedure, as a golf player who is in good form may not need to waggle his club before making a drive. But in describing all the possible precautions against error, I did so for the benefit of the novice, who, as he gains experience, will be warranted in dispensing with some of them, while retaining others, according to the circumstances of each case.

The examples quoted by Mr. Gemmell are full of suggestion; it is by contact with such facts that a man acquires the judgment which enables him to detect the weak points of any estimate, and so avoid them. No contribution to this discussion will be more valuable than these transcripts from experience as given by Mr. Gemmell, if they emphasize the enormous variety of conditions to be faced in the valuation of mines.

Impatience with an apparently needless consideration of niceties of method has become apparent in the latter part of this discussion on sampling, and a letter received from a veteran engineer voices this sentiment by suggesting that too much emphasis is being placed upon useless details, which have the effect of obscuring the essential facts.

Well, there is something to be said for that; an engineer should not get so tied up with his paraphernalia and methods as to lose sight of the purpose of it all, for, if he does that, he will resemble the centipede who got along very well on his multitudinous legs until the scorpion asked him which leg he put out first, and thereupon the centipede became so self-conscious that his extremities became all tangled up and he fell by the wayside. There

[26]See page 184.

is a happy medium between discarding a proper procedure and becoming the victim of it, to be so 'practical' as to neglect precautions and to be so 'technical' as to lack sense of proportion. This entire consideration of a difficult part of mining practice illustrates the importance of the personal factor. The mathematical demonstrations and occasional short-cuts, such as have been described by Messrs. Channing, Hoffman, Stevens and Mathez, are all suggestive of the fact that the methods evolved by experience, if good, are logical; but beyond this there is an insistent element present in all estimates of ore in a mine, that is, the personal equation, which cannot be expressed by any algebraic sign save x. No branch of professional work, not even the management of men, requires more resourcefulness and skill; for this reason it is considered one of the severest tests of an engineer's capacity. If, therefore, the importance of this subject has become recognized increasingly during the last few years, it is good evidence of the emergence of mining from the mists of speculation on to the firm ground of serious business.

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