Mininig and Metallurgical Investigations

BY THE

DEPARTMENT OF MINING AND METALLURGICAL RESEARCH

of the UTAH ENGINEERING EXPERIMENT STATION

Bulletin No. 10

(Revised)

Mine Sampling

AND THE

Commercial Value of Ores

BY

ROBERT S. LEWIS, E. M.

Professor of Mining

Price 35 Cents

Printed by

THE UNIVERSITY OF UTAH

1931

DEPARTMENT OF MINING AND METALLURGICAL RESEARCH

The Department of Metallurgical Research of the University of Utah was organized in 1914, as a research department to co-operate with the United States Bureau of Mines in research work, for the study of fundamental and economic problems confronting the mining industry of the State. Summaries of these investigations were prepared from time to time, and published as reports of the Department of Metallurgical Research and Bureau of Mines publications.

In 1927 the Department of Metallurgical Research was reorganized and became what is now the Department of Mining and Metallurgical Research.

By reason of the co-operative agreement between the University and the U. S. Bureau of Mines, the Supervising Engineer of the Intermountain Station of the Bureau of Mines also acts as executive head of the Department of Mining and Metallurgical Research of the University.

Prior to the re-organization of the work of the Department of Mining and Metallurgical Research, as above mentioned, a bulletin was issued each year by the Department entitled, "Research Investigations," in which was embodied reports, technical papers, and so forth, giving the results of the work which had been carried on during the previous fiscal year.

With the re-organization of the Department, it was decided to hereafter publish the information obtained as a result of the work of the Department, either in the form of (1) technical bulletins, (2) technical papers, or (3) circulars of information.

After the reorganization of the Department, an Advisory Board was formed, from among those engaged in the mining industry, as regards the co-operative work that is being carried on by the University and the Bureau. The personnel of this Advisory Board is as follows:

D. D. MOFFAT, Vice-Pres. and Gen. Mgr., Utah Copper Company, Chairman.

J. O. ELTON, Mgr., International Smelting Company, Vice-Chairman.

G. W. LAMBOURNE, Pres. and Mgr., Park Utah Consolidated Mines Company.

E. J. RADDATZ, Pres. and Gen. Mgr., Tintic Standard Mining Company.

W. J. O'CONNOR, Mgr., Utah Dept., American Smelting & Refining Company

W. H. EARDLEY, Asst. Mgr., United States Smelting, Refining & Mining Company.

W. MONT FERRY, Managing Director, Silver King Coalition Mines Co., and President, American Silver Producers' Association.

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INTRODUCTION

The United States Bureau of Mines, the Utah Chapter of the American Mining Congress and the University of Utah have a cooperative agreement whereby mineral samples, sent to the laboratory at the University, will be tested without charge. This work is qualitative only. The different minerals or metals in the samples are determined, but no assays are made except upon special request. In such cases, a price 10 per cent higher than that of the local assayers is charged. It is not the purpose of the University to engage in competitive commercial work.

The wisdom of this agreement has been proved by experience. If assays were made free of charge, the laboratory would be deluged with a great number of samples, fully nine tenths of which would be practically worthless because they were not taken either to represent the average mineral content of the deposit or to give any definite idea of its size. The samples received are usually "grab" samples, pieces picked up here and there, taken from the richest part of the outcrop or surface showing. Not only are such samples of little use for determining the worth of the mineral discovery, but they often convey a wrong idea of the value of the deposit. The incident of the Mexican who was sent to sample a rich gold vein is worth repeating here. He was found to be carefully picking out only rich pieces for the sample. When asked why he did not take the whole vein as it occurred, he replied to the effect that anyone could see that part of the vein had no value, and why should worthless material be included in the sample? This argument seemed to him unanswerable.

To those not familiar with the business of mining, the meaning of an assay report is often confusing. For convenience, the unit of weight taken is the ton. In the United States this ton is understood to be the short ton of 2,000 pounds avoirdupois weight. Should any other ton, such as the metric tons of 2204.6 pounds or the long ton of 2240 pounds, be used its weight should be specifically stated. Assays are reported in terms either of dollars or of the quantities of the metals present in a ton of material. Gold assays are often reported in dollars, since the price of this metal is fixed at $20.67 per ounce. In their calculations assayers most always use the round number $20 instead of $20.67. In general, the precious metals, gold, silver and platinum, are reported in ounces, but the base metals, copper, lead, zinc, antimony, etc., are reported in per cents. The meaning of per cent will be explained below. Consider for example a gold assay reported in dollars. This simply means that the particular sample in question is to be valued at the rate of so many dollars per ton. If the assay report on a sample is given as $100 per ton, it means that a ton of material exactly like the sample contains 5 ounces of gold which figured at $20.00 per ounce would equal $100.00, but it does not mean that a ton of material has been assayed. Suppose that the sample from which the assay was made weighed 10 pounds, then the actual value figured at $20.00 per ounce of the sample would be 1/200 of $100 or 50 cents, since its weight is 1/200 of a ton. There is no guarantee that a large quantity of $100 "ore" has been found, or even that there is a ton of it. Indeed, the sample itself may be all the rich material there is in the deposit! When a sample truly represents the average value of a number of tons, the total value is, of course, found by multiplying the number of tons by the assay value. However, most prospectors' samples are not properly taken. The only significance that can be attached to them is that they prove the presence of certain minerals. Little or nothing is to be learned from them about the average mineral content or size of the deposit.

A few samples have been sent to the laboratory by mail accompanied by a request something like this: "We have a whole mountain of this stuff, what is our mine worth?" This Bulletin has been written to show why it is impossible to answer such a question. Its purpose is to explain briefly and in a simple manner what constitutes a mine, how samples should be taken, how mineral content and tonnage of an ore deposit are determined and how its commercial value is calculated.

WHAT IS A MINE?

A mine may be defined as a deposit of one or more valuable minerals that can be worked at a profit. The consideration of a number of points is implied in this definition, and the most important ones are referred to below.

1—Purchase Price. It seldom happens that the discoverer of an ore deposit possesses the funds necessary for the development and operation of the property. Again, it may be necessary to consolidate various claims or groups of claims held by different owners. Usually, the first step in the making of a mine is the purchase of the property.

2—Exploration. Various methods of exploring a mineral deposit are used. The choice of the method to be followed in a particular case depends upon the completeness of the knowledge that is available regarding the size and shape of the deposit, its position in the ground, the physical nature of the deposit and of the encasing rock, the length of time available for exploration and the amount of money to be devoted to exploration. A shaft may be sunk and levels and drifts, as the horizontal workings are called, run through the deposit. An adit, commonly called a tunnel, may be driven from the surface, into the mountain on a vein, fissure, dike or contact or the adit may be driven in some distance to intersect the vein or fissure, which is then followed by running drifts in either direction. Other methods of exploration are to use diamond drills or churn drills. These are set up on the surface of the ground and holes are drilled through the ore body. The diamond drill gives a solid section or core of the rock drilled, but the churn drill reduces the material to a fine mud or sludge. The length of holes is noted and the drilling or cores are assayed. Sometimes two methods are combined, drill holes being driven from points in the underground workings. For such work the diamond drill is almost in variably used. Whatever method is employed, its purpose is to secure representative samples of the ore body and measurements of its extent, so that its mineral content and tonnage can be calculated. The exploration work of one large company comprised 23,097 ft. of diamond drill holes, 3,955 ft. of shallow shafts and 1,513 ft. of drifts.

3—Metallurgical Treatment. No two ore deposits are exactly alike. Each is a particular problem in itself, and, in order to determine the proper treatment for the ore, it may be necessary to carry out a long and expensive series of tests. On the other hand, the nature of the ore may be such that only a very simple treatment is required. A skilled metallurgist should always be employed for this work. Hundreds of thousands of dollars have been lost in mining ventures because this important point was not thought to be worthy of consideration.

4—Plant and Equipment. After a tonnage of ore sufficient to justify the building of a mill has been developed and the proper treatment of the ore has been decided upon, the next step is to build the plant and equip the mine with the necessary machinery. The daily capacity of the plant should be decided upon only after the nature and size of the ore body is known and a number of financial considerations have been taken into account. Wagon roads, railroads, office buildings, bunkhouses, boardinghouses and store rooms would all come under this heading.

5—Operating Expense. Under this title should be included the cost of breaking the ore and getting it to the surface, of transporting it to the treatment plant, of the treatment itself, and the transporting and marketing of the product, also all office expense, insurance and taxes. In addition to breaking sufficient ore to keep the plant running, enough ore must be found or developed to replace that taken out and this must be done in other parts of the mine in order not to interfere with actual mining operations. There is no immediate profit to be derived from this work, but it is properly charged against operating expense.

Returning now to our definition of a mine, we should have a better understanding of what "worked at a profit" means. If the value of the deposit is such that the working of it would return to the owners only the purchase price, cost of exploration, cost of determining the method of treatment, cost of plant and equipment and the cost of operation, the working of the property would not be good business, since, at the end of the life of the mine, the owners would be in the same financial position as at the beginning of operations. They would have their money back, but they would have nothing to show for their trouble. The mine must yield an additional profit to serve as interest on the investment. Just what this amount should be depends upon the comparative safety of the investment. Thus for a large mine, of assured long life and so situated that labor and supplies can be easily obtained, an interest return of 10% on the investment might be considered satisfactory, but for a mine in a foreign land, where labor is scarce and inefficient and where supplies must be transported long distances as high an interest rate as 50 per cent might be demanded. When a mineral deposit will stand this test it may be safely called a mine.

It is evident that the mineral content and tonnage of the ore in a mine can be determined with a fair degree of accuracy before any large amount of ore has been taken out, but the cost of the plant and operation can only be estimated. The financial success of the enterprise depends upon how well these estimates will be found to agree with the actual cost of construction and operation. Several of the large mining companies have spent millions of dollars for plant and equipment before a single pound of metal was recovered from the ore, and yet subsequent operation has proved the correctness of the estimates of the engineers. Training and experience are required to make a mining engineer. Therefore, when a man leaves his lifelong business and, without competent advice ventures into mining and comes to grief, there is little reason for wonder. The case is plainly one of cause and effect.

WHAT IS A PROSPECT?

The term prospect is usually applied to a mineral deposit the extent and value of which is only slightly known. The surface showing or outcrop may be the only indications of mineral, or a few tons of ore may be exposed by sinking a shallow shaft or driving a short tunnel in from the hill side. Strictly speaking a tunnel should run entirely through the hill thus leaving both ends open to the atmosphere. A working that is driven into the hill and stops there should be called an adit.

While on the subject of definitions, it may be well to define "ore", a term that is often so loosely used as to be confusing. Ore may be considered as mineral bearing material that can be extracted from place, treated by some mechanical process if necessary to make a marketable product, and then sold at a figure that yields a profit after all costs have been deducted. The difficulty with the definition lies in the idea of profit. If the market price of a metal drops suddenly, ore that yielded a slight profit yesterday is not ore today, since it can no longer return a profit. A mineral deposit that cannot be worked at a profit because it is many miles from a railroad, might become a highly profitable mine if another railroad should be built to pass near the property. Again, the discovery of a new method of treatment may make a hitherto worthless deposit very valuable.

One of the most difficult problems that a mining engineer has to face is the valuing of a prospect. There are so many uncertainties to deal with that it is impossible to make an exact valuation. The extent of the deposit, whether it grows richer or poorer with depth and at what point oxidized minerals give way to sulphides can only be estimated from evidence that is all too slight. A prospector seldom, if ever, possesses the knowledge that is necessary for making these deductions, but he should be able to measure the outcrop, take representative samples and describe his find in fairly accurate terms. By so doing he will be far more likely to secure financial assistance than if he comes back with a few rich samples, picked up at random, and a highly colored story of the great size of the deposit he has discovered.

SAMPLING

If a ton of ore is crushed to the necessary degree of fineness, thoroughly mixed and a small sample cut out, the sample may justly be taken to have the same average mineral content as the original ton. However, the sampling of ore in place presents a different problem. It is not possible to crush the entire deposit before sampling, so a small quantity is broken from the outside or "face" of the deposit in such a manner that it represents the average condition of the material lying around it. Ore bodies are never exactly the same in all parts. The mineral content varies from place to place. For this reason a single sample cannot be relied upon to give the average mineral content of the entire deposit. A number of samples must be taken, and the distance between them or the "sampling interval," as it is called, depends upon the uniformity of the ore. If the content of the ore varies but little from one point to another, the sampling interval is greater than in the case of ore that is spotty or contains the valuable mineral in scattered bunches. An extreme case is presented by a vein in which patches of coarse gold are scattered through quartz like plums in a pudding. Such a condition would test to the utmost the skill of an experienced engineer, and a beginner had better not attempt to sample a deposit of this kind. It should be remembered that it is the irregularity of the distribution of the mineral through the ore rather than the richness of the ore that governs the sampling interval. Samples taken at long intervals are just as reliable if the ore is rich as if it is poor, provided both ores are of uniform content throughout. For most medium or low grade gold ores, as well as for copper, zinc and lead deposits, a distance of 10 ft. between samples is very often taken. For rich gold ore, the distance may be reduced to 5 ft., or even 1 ft. if the gold is irregularly distributed. The large low grade copper deposits have been quite accurately sampled by churn drill holes placed 200 ft. or more apart. However, the ore in these deposits is extremely uniform in character. A prospector who has made what seems to be a valuable discovery, faces a difficult situation. He should take all the samples that would be of value in proving the character of the deposit, yet he seldom has the facilities for cutting down the samples and transporting them to an assayer. It is dangerous to offer a fixed rule for taking samples, because each mineral deposit must be treated as a separate problem, and what might be a rule for one cannot be applied to the next. However, it is suggested that the distance between samples should not be greater than 10 feet. At best this sampling is only of a preliminary nature. Nevertheless, it may be a very good guide when planning the course of future operations.

The common method of taking samples is to cut a groove or channel across the ore. The tools used are hammers and moils. Single-hand hammers are used where the rock is easy to cut. One man catches the sample in a suitable container, while the other does the cutting. Where the rock is hard, a double-hand hammer is required, and one man does the striking while another holds the moil or cutting tool. A third man catches the sample. The moil is a piece of ⅝ or ¾ inches drill steel from 10 to 12 inches long. One end is brought to a square or pyramid shaped point, though there is less danger of the point breaking if it is cut across the tip to form what is called a diamond point. Chisels or gads are often used to advantage in soft rock such as slate or some schists. A gad has a flat wedge shaped point like a cold chisel. The sample may be caught in a small box, in a duck or canvas bucket or on a suitably sized piece of canvas lying on the floor of the adit or drift directly under the face being sampled. The bucket should be from 9 to 10 inches in diameter and from 12 to 14 inches deep. A ring of iron or copper wire is used to form the top. A handy container can be made by bending a heavy wire or a piece of round iron of small diameter into a rectangle about 8 by 10 inches, and letting the ends project to form a handle about a foot long. A piece of light duck is then formed into a bag or a funnel about 12 inches deep and is sewed to the iron.

The size of the groove or channel cut may vary from ½ inch deep and 2 inches wide to 1 inch deep and 6 inches wide. Large samples are better than small ones, but the heavy labor involved in cutting a large sample from hard rock and the time required for crushing and cutting down are good reasons for taking as small a sample as seems reliable. Even then it may require several hours of the hardest kind of work and the dulling of a number of moils to cut a single satisfactory sample. Before sampling, the face or surface of the ore should be thoroughly cleaned of dirt and loosely adhering rock, and, if rough and jagged, some trimming should be done. This will insure that nothing but fresh and truly representative material goes into the sample. A smooth surface for sampling is very desirable, but, as a matter of fact, rather rough faces are always left even after considerable labor has been spent in trying to make them smooth. It is a question of doing the best that can be done under the circumstances. The prime requisite of a good sample is that every inch or every foot of it should yield the same volume (not weight) of material. In rock that is badly fractured or that contains alternating hard and soft bands a smooth and uniform cut cannot be made, but it is possible to get approximately the same volume of material per foot of length. This requirement must always be fulfilled, no matter how much work it entails, for careless sampling is worse than none at all. Should a large piece fall down, the size of the cut should be increased to give the same relative amount for the rest of the sample, or else the sample must be discarded, the face trimmed and a new cut made either in the bottom of the old one or as close as possible on one side.

As soon as a sample has been taken it should be placed in a small canvas bag, numbered and tied with a strong string. The bag should not be numbered on the outside, but a piece of heavy paper, or better a linen tag is marked with an indelible pencil. The paper is folded two or three times with the mark inside and is then dropped into the bag. A brass or tin tag stamped with a number is even better. If samples are greatly shaken while being carried, especially if the ore is damp, paper tags may be softened and scratched so the number on them cannot be read when the sacks are opened. Should two or three more bags be required to hold the sample, each is given the same number. Bags, well filled but so that they can be satisfactorily tied, will hold the following quantities of quartz or low grade copper ores; Bags 5x9 inches about 3½ pounds; bags 5x12 inches about 4½ pounds, bags 7x14 inches about 8 pounds and bags 12x16 inches about 28 pounds.

Where a vein is banded or composed of a number of different streaks of ore, which have a different mineral content or which are of different physical character, fractional samples should be taken. Instead of a single sample being cut across the whole width of the vein, each band is sampled separately. The same general number is used for all cuts, but each tag has an additional mark to show what part or fraction it represents. Thus the mark No. 23—F2. would mean that this was the second part or fraction of sample, the various fractions may be combined as desired. Fractional sampling is also followed when the deposit is more than 4 feet wide. In fact, many engineers state that no single sample more than 5 feet long should ever be taken. A single sample over a great width does not show whether the valuable mineral is evenly distributed along the cut or occurs all at one spot. Such information is of great use in determining the value of the deposit. A record of each sample should be kept in a note book. This record should contain a statement of where the sample was taken, the width the sample represents and a brief description of the appearance of the deposit at this point. Certain undesirable minerals, may be seen to be present. The ore may be very hard, or it may be soft or full of clay. Again, the valuable minerals may not only be scattered through the vein, but may extend out into the surrounding or "country rock," as it is called, so that it is necessary to carry sampling some distance beyond the vein in order to determine the limit of the ore. All payable material, whether vein matter or country rock, would be taken out in the mining operations.

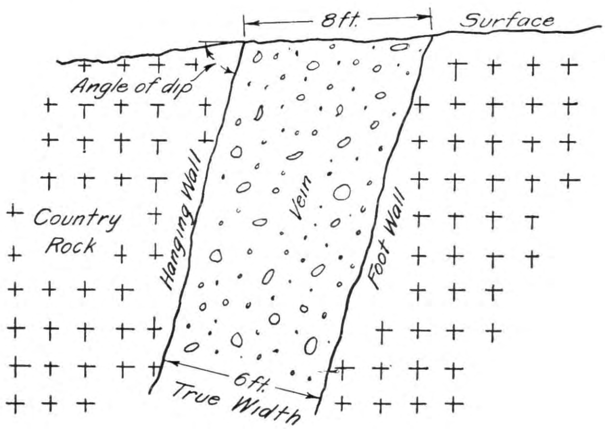


Figure 1

It has been stated that the width a sample represents should be noted, but this requires further explanation. Let **Figure 1.** represent a mineral bearing vein having an outcrop plainly visible at the surface. A sample taken across the full surface width would be 8 feet long, but the true width of the vein, measured perpendicularly between the walls is only 6 feet. If the walls of the vein are clearly defined, the dip, or angle the vein makes with the horizontal, can be measured and the true width calculated by trigonometric methods. Digging out the top of the vein to expose both walls will permit the true width to be measured. Obviously, it would be very misleading to report the vein as being 8 feet wide. For a given depth, much more ore would be expected than was really in the deposit.

In **Figure 2** is shown a section of an under-ground working or drift. The side **b-c** is parallel with and close to the vein wall. A novice at sampling would be very apt to sample the whole roof and sides of the drift, cutting a channel from **a** around to **c.** However, the length along the side **b-c** represents no width of vein, since it is parallel with its dip. The sample should be cut either from **a** to **b,** or **a** to **c,** and the true width of the vein measured along a perpendicular between the walls, such as the line **a-d.** The bottom of a drift is likely to be wet and is generally covered with dirt, moreover the haulage track is in the way. These conditions make sampling along the bottom a difficult task.

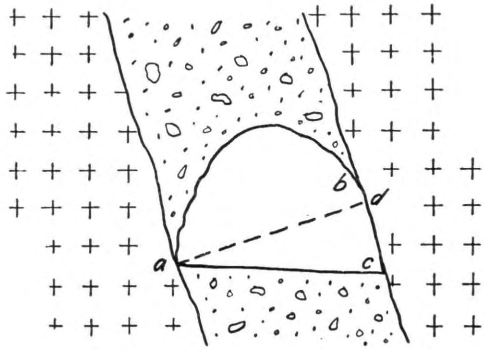


Figure 2

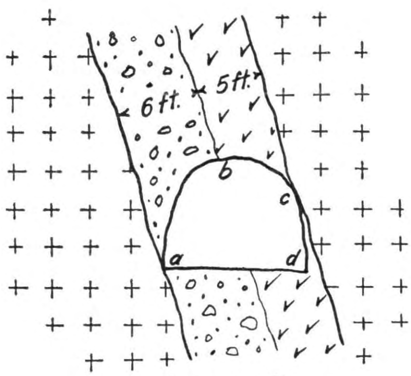


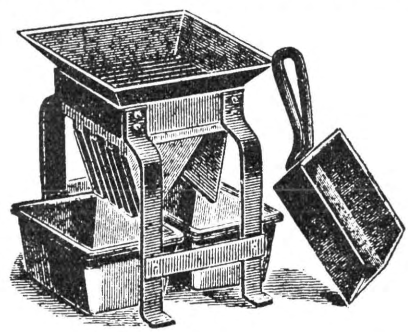
Figure 3

In **Figure 3,** the vein is composed of two bands and these should be sampled separately. The first fraction should be taken from **a** to **b** and represents a width of vein equal to 6 ft. The other fraction should be taken from **b** to **c** and represents a width of 5 ft. If the second sample were taken from **b** to **d,** the part **c-d** would be a duplication of some of the sample **b-c,** thus making the sample out of proportion and unsatisfactory.

Where the vein walls are clearly defined a string or a board may be placed perpendicular to the dip and the true width measured along this direction. Where the walls are indistinct or the vein is broken or faulted, evidences of the real dip may be so slight that only a trained geologist can interpret them correctly.

After samples have been taken, they should be carried to some suitable place and there reduced in bulk to a size that is convenient for transporting to the nearest assay office. It is far easier to handle and ship samples of 4 or 5 pounds weight than if they weighed 50 or 100 pounds. Where the cutting down has been properly done, the small sample is fully as reliable as the larger one.

A single sample, taken in the manner described above, will be a mixture of fine and coarse pieces. It would be wrong to pick out a little here and a little there, put these bits together and expect them to have the same mineral content as the original sample. The proper procedure is first to crush the entire sample to a suitable degree of fineness, mix it thoroughly and then cut out a part. This part should then be crushed, mixed and another cut taken. The process is repeated until the final cut or sample is as small as desired. The degree of fineness to which the sample must be crushed before the first cut is taken depends upon the nature of the ore. Ore of uniform grade does not need to be crushed as fine as ore that varies widely in grade. For samples of copper, lead, zinc and most medium or low grade gold ores a good rule to follow is that no sample that contains particles larger than ¼ inch in size should be cut down. All pieces should be crushed to this size before any cut is made. When crushed to this size and then well mixed, the sample can be cut down to about 10 pounds on a mechanical splitter or by quartering. The mechanical splitter is a device which divides a sample into two equal parts. The material must be poured evenly on the whole length of the splitter to insure accurate results, and the splitter must have the same number of divisions on each side. The methods of quartering consists in mixing the sample by rolling on a piece of canvas or oil cloth, forming it into a cone, flattening the cone until the mass is from 2 to 4 inches thick and then dividing it into quarters in the same way that one would cut a pie. Two opposite quarters are selected and the others are rejected. For further reduction, the sample of 10 pounds should be crushed to 10 mesh (about 1/16 inch) when, after a thorough mixing, a finished sample of from 3 to 4 pounds may be cut out. A channel 1 inch deep by 6 inches wide will give, in quartz, a weight of about 7 pounds per foot of cut. Where a vein is narrow and a smaller size channel is made, the weight of the whole sample may be so small that there is no need of cutting it down, and it is sent directly to the assayer. Fine crushing and thorough mixing before each cut is taken are absolutely essential if a reliable sample is to result. It is better to overdo the work than to slight it. When it is considered that the content of an ore body is calculated from samples whose total weight may be only 1/10,000 part, or even less, of that of the entire deposit, it is plain that too great care in the handling of the sample cannot be exercised. The most accurate sampling can be rendered worthless by carelessness in cutting down.



CALCULATING MINERAL CONTENT AND TONNAGE

The first calculation to be made, after samples have been assayed, is the combining of fractions into a single sample. For this work arithmatical averages should never be made. All averages should be weighted, that is assays should be rated according to the quantity of material they represent. The method of carrying out such calculations is most easily followed by means of **Table 1,** which shows the finished record of a sample taken in three fractions.

Table 1.

1	2	3	4	5	6	7	8
		Assay					
Number Sample	Width Inches	Gold ounces	Copper per cent	Description	Inches by Ounces	Inches by Per cents	Average for Entire Sample
20-F1	30	.25	2.0	Hanging wall. Taken on side. Firm hard quartz	7.5	60	Average gold content is 27.5 ÷ 90 = .305 ounces for 90 inches.
20-F2	20	.20	3.0	Soft quartz containing much clay.	4.0	60	Value @ $20 per oz. is $6.10. Average copper content is 184÷90 =2.04 per cent.
20-F3	40	.40	1.6	On foot wall side. Quartz heavily stained with iron.	16.0	64	Value of copper at 15c per pound is 2000x 2.04÷100x15 = $6.12 per ton.
Total or Average	90	3|.85 .28	3|6.6 2.2		27.5	184	Total gross metal value per ton is $6.10+ 6.12=$12.22.

The widths are given in round numbers simply to make the calculations easy. Explanation: Columns 1, 2 and 5 are filled in when the samples are taken. Columns 3 and 4 are copied from the assay report. In columns 6 and 7 are found the weighted averages for each metal contained in the sample. Thus, column 6 is found by multiplying column 2 by column 3, and column 7 is the product of columns 2 and 4. The sum of the products in column 6 divided by the sum of the widths gives the average gold content for the whole sample. The average per cent copper is found in a similar manner. Arithmetical averages are given at the bottoms of columns 3 and 4. These are quite different from the true averages. The value of the sample is found by multiplying the metallic content by the market value of the respective metals. In the example given, gold is taken at $20 per ounce and copper at 15 cents per pound. One per cent means 1/100 part or 20 pounds per ton, consequently 2.04 per cent means 2.04x20 or 40.8 pounds of copper per ton of material. As stated above, assays are generally reported in ounces per ton for gold and silver and in per cents for the other metals. Since the market value of most metals varies from time to time, it would not do to report assays in terms of dollars and cents unless the metal prices, from which these figures were calculated, are also given, otherwise, the actual metallic content of the sample would not be apparent to the one reading the report.

Fractional sampling is necessary in order to show what part of the deposit is ore, and the value of such sampling will now be explained. For the purpose of discussion, let it be assumed that the vein contains copper, that no gold is present, and that the assays are as given in column 4. Let it be further assumed that no material can be considered as ore that contains less than 2 per cent copper. It is evident that fraction F3 must be rejected, that the width of ore is only 50 inches and that its average copper content is 2.4 per cent. (The reader should work this value out for himself.) Since Table 1 shows that the average content for the whole 90 inches of vein is 2.04 per cent copper, it might seem that the whole vein should be considered ore. It is a good rule to remember that no material, that will not yield a profit by itself, will be profitable when mixed with material of higher grade, yet many men have deceived themselves on this score. The including of the 40 inches of 1.6 per cent material has lowered the average copper content from 2.4 to 2.04 per cent. From a financial standpoint, the result is the same as though the 50 inches of 2.4 per cent material and the 40 inches of 1.5 per cent material had been sold separately, and the profit on the former had been cut down by the loss on the latter.

Suppose that a vein one foot wide contains gold to the amount of 1 ounce or $20.00. If the assay only is reported, and the width of the vein is not given a true idea of the value of the deposit is difficult to form. On the other hand if it is known from previous experiences with similar deposits in regions where costs of labor and supplies are about the same that a vein 4 feet wide can be mined for $5.00 a ton, and that the width of this vein is 1 foot, a more definite idea of its value can be formed. In general, it may be stated that a miner should have an opening 4 feet wide if he is to work to advantage with a machine drill, and that the cost of working a narrower deposit will increase in much the same proportion as the deposit becomes narrower than 4 feet. Thus for a deposit 1 foot wide the cost of working would be $20.00 per ton of vein, due to the fact that the cost of mining the additional 3 feet of barren rock must be born by the 1 foot vein. Thus in the case of a vein 4 feet wide, containing gold to the amount of $10.00 per ton a profit might be realized, whereas a vein containing $20.00 a ton in gold but only 1 foot wide would give no profit.

This discussion assumes that the vein material is of such a nature that it would break with the wall rock and could not be sorted out. It is true that the application of a special method of mining might make it possible to work this narrow vein at a profit. However, estimates of tons of ore and the cost of mining are based on definite widths of ore, consequently it is necessary to take samples in such a way that they furnish complete information regarding the extent of the ore body.

The method of finding the average of a number of samples is quite similar to the combining of fractions into one sample.

Let W_1, W_2, W_3, etc., be the length of each sample.

Let V_1, V_2, V_3, etc., be the assays of the samples.

Let L_1, L_2, L_3, etc., be the lengths along the deposit that the samples represent. See the lower part of Fig. 4. Here L is 10 feet, as each sample is assumed to represent the value of the ore to a point on either side half way to the next sample. For sample No. 10, L= 10 feet, W=44 inches, V=$10.00.

$$\text{Then the average assay} = \frac{W_1 V_1 L_1 + W_2 V_2 L_2 + W_3 V_3 L_3}{W_1 L_1 + W_2 L_2 + W_3 L_3} \text{ etc.}$$

(Formula 1)

The length a sample represents is taken as half the distance between it and the two adjacent samples. Thus where the distances to the adjacent samples are 10 feet on one side and 15 feet on the other, the length represented by the sample is 5+7½=12½ feet. Where all samples are the same distance apart, $L_1=L_2=L_3$, and this factor can be dropped from the equation.

$$\text{Then the average assay} = \frac{W_1 V_1 + W_2 V_2 + W_3 V_3}{W_1 + W_2 + W_3} \text{ etc.}$$

(Formula 2)

Since this greatly simplifies the computations, it is customary to use the same sampling interval throughout the work, unless some special condition prevents.

Figure 4 shows a block of gold ore 40 feet high by 30 feet long, which has been sampled at 10 foot intervals. The samples are numfered in the order in which they were taken, and the widths and assays are also given. It should be noticed that the vein is fairly regular in width and is so uniform in character that no fractional samples need be taken. The gold content has been figured at $20 an ounce to give the value in dollars. Even figures are taken to simplify the calculations. The block is shown in perspective, and the two sides BC and CD, that are not visible, are given in separate sketches. Since the sampling interval is the same for all the work, the simplified formula for calculating the average assay can be used.

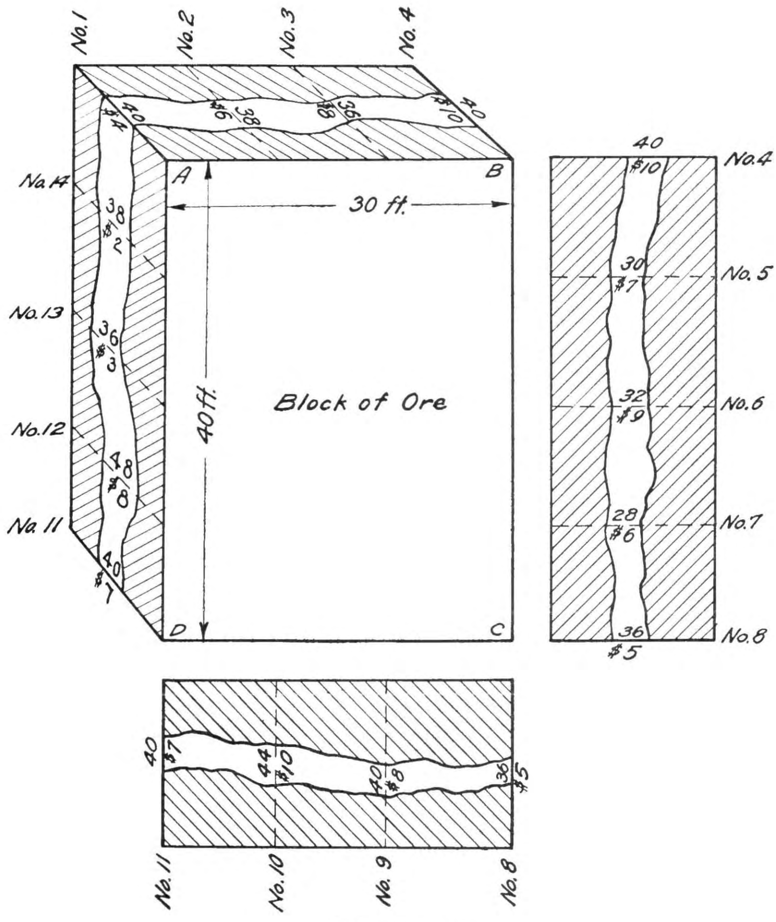


Figure 4

The following calculations give the average width of the vein and its average assay along each of the four sides of the block. It remains to combine these to give the average assay and width of the vein for the entire block. Another item must now be considered, and that is the length of each side of the block. The side BC is longer than the side CD. It therefore must be given more weight in taking up the value of the block because it represents a greater length of vein. Hence, there are three factors, length, width and assay to multiply together in exactly the same manner as the widths and assays for the various sides were combined.

For side AB.

Sample No.	Width Inches	Value Dollars	Inch Dollars
1	40	4	160
2	38	6	228
3	36	8	228
4	40	10	400
	154		1076

Average width is 154÷4=38.5 in. or 3.2 ft.

Average assay is 1076÷154=$6.98.

For side BC.

Sample No.	Width Inches	Value Dollars	Inch Dollars
4	40	10	400
5	30	7	210
6	32	9	288
7	28	6	168
8	36	5	180
	166		1246

Average width is 166÷5=33.2 in. or 2.76 ft.

Average assay is 1246÷166=$7.52.

For side CD.

Sample No.	Width Inches	Value Dollars	Inch Dollars
8	36	5	180
9	40	8	320
10	44	10	440
11	40	7	280
	160		1220

Average width is 160÷4=40 in. or 3.33 ft.

Average assay is 1220÷160=$7.62.

For side AD.

Sample No.	Width Inches	Value Dollars	Inch Dollars
11	40	7	280
12	48	8	384
13	36	3	108
14	38	2	76
1	40	4	160
	202		1008

Average width is 202÷5=40.0 in. or 3.36 ft.

Average assay is 1008÷202=$4.99.

For the Whole Block

Side	Length in Feet		Width in Feet		Square Feet		Assay Dollars		Square Feet Dollars
AB	30	×	3.2	=	96.0	×	6.98	=	570.08
BC	40	×	2.76	=	110.4	×	7.52	=	830.21
CD	30	×	3.33	=	100.0	×	7.62	=	762.00
AD	40	×	3.36	=	134.4	×	4.99	=	770.66
	140				440.8				3032.95

Average width of vein for the block is 440.8÷140=3.14 feet.

Volume of block in cubic feet=30×40×3.14=3768.

Assuming a tonnage factor of 13 cubic feet per ton for the ore in place (not broken) the block contains 3768÷13=289.8 tons of ore.

The average assay of the ore is 3032.95÷440.8=$6.88 per ton.

Total gross metal value of block is 289.8×$6.88=$1,993.82.

To find the combined or total value of several blocks and in this way to determine the value of the whole mine use the following method.

1. Multiply the total tons in each block by the average assay of the block to give a tons × dollars product.
2. Add the tons × dollars products and divide this sum by the sum of the total tons in each block. This gives the average assay for all the blocks.
3. Total tons in the mine is the sum of the total tons in each block.

Keeping this example in mind, several points may now be discussed. In actual mining operations the size of the mass of ore that has been developed or blocked out, that is exposed on all four sides by mine workings is seldom as small as that shown in Figure 4. These small dimensions were chosen to shorten the calculations. In large mines, ore may be blocked out for two or three years before it is removed from place. Underground workings are costly to drive and maintain, so economy requires that the blocks be as large as is consistent with reliable sampling. Samples actually represent only the outside faces of the block, and their use in calculating the average assay of the ore is an assumption that the block is of the same average assay within as along the outside. Experience has shown that within certain limits, this assumption is justifiable. In general, a distance of 200 feet on a side is about the maximum length that a block should have, and this would only be permitted when the ore is quite uniform throughout. On the other hand, 100 feet is about the minimum length that would be required. Where drill holes are used to value and block out ore, their spacing should conform to the above requirements. In this case, the only underground workings driven are those necessary for the extraction of ore. (This does not consider any workings used to check drill hole results.)

A block of ore, though exposed on four sides, may contain a core or center of worthless material, called a "horse." The calculated value of the ore would then be too high. However, this is one of the risks of mining. Ore blocked out in this manner is considered as being in the highest stage of development, and is customarily rated at its calculated value. Ore blocked out on only two or three sides should not be considered as having its value proved as conclusively as though blocked out on four sides. Thus in **Figure 5,**

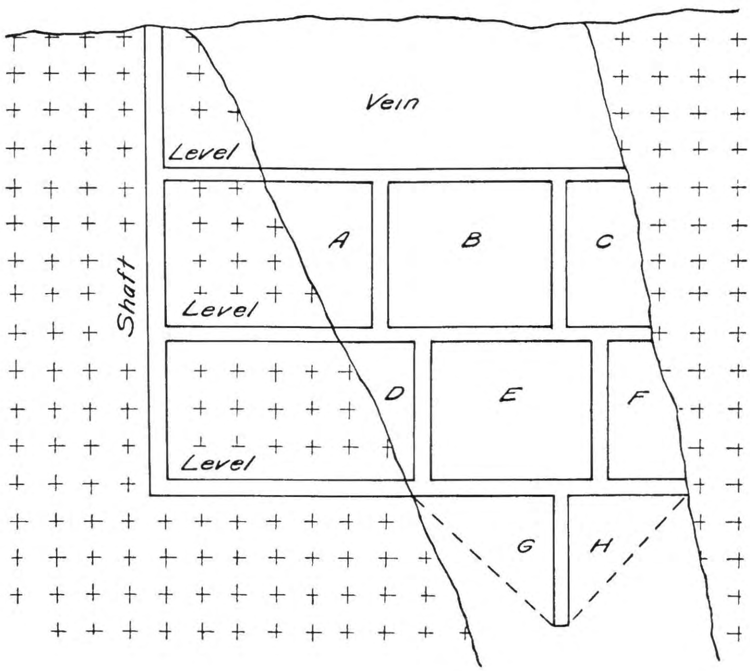


Figure 5

blocks B and E are proved ore, blocks A, C and F, are partly proved, being developed on three sides, while blocks D, G, and H are still less developed. In estimating the tonnage of the different blocks, the engineer would take blocks B and E at their full calculated tonnage, but the other blocks would have their calculated tonnage modified according to their state of development. For example blocks developed on three sides might be considered as being equivalent to ¾ of a full developed block, and the factor ½ might be applied to the blocks developed only on two sides. The actual factor to be assigned to the various blocks is decided upon by the examining engineer only after a careful study of the conditions has been made.

Where only a little development work has been done, as in the case of a prospect, it may be desirable to make an estimate of the possibilities of the deposit. Such cases are more easily illustrated than described, and a number are given in **Figures 6 to 10.**

In these figures the line marked outcrop is assumed to be mineralized for its entire length from A to B, and the underground workings are all assumed to be in ore. The possible tonnage is included within the boundary lines of the figures. The dotted lines show the assumed limits of the ore. Only in Figures 9 and 10 is any ore blocked out on all sides. Estimates of mineral content and tonnage are made in the same manner as for the block shown in Figure 4. Fractional samples are first combined into single samples, and all samples along one side are averaged to give a single assay and width. The various sides are then combined to give the assay and width for each block. The area times the width gives the volume in cubic feet, and this divided by the tonnage factor shows the number of tons in the deposit. A word of caution is needed here. Because of incomplete development, it must be remembered that this is not proved ore, and it should not be considered as such. A thorough exploration of the deposit may show later that much of what was supposed to be ore is not really ore. Prospectors and men who do not know that many apparently rich deposits have turned out to be of little value, are very likely to be too optimistic about their holdings. Their enthusiasm gets the better of their judgment and they soon convince themselves that they have a most valuable mine. Once in this state of mind, it is very hard to get

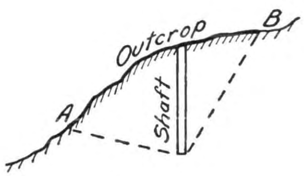


Figure 6

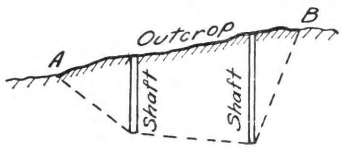


Figure 7

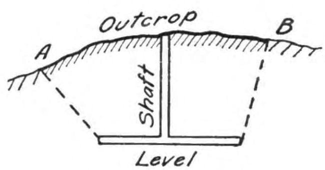


Figure 8

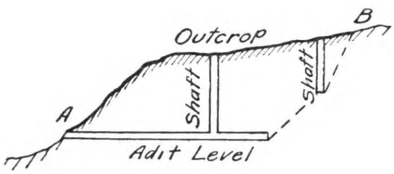


Figure 9

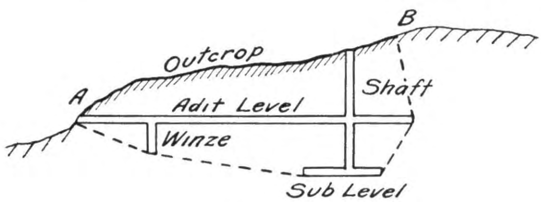


Figure 10

them to see conditions as they really are. Until the deposit has been fully developed and as completely sampled as sound engineering practice requires, no false hopes regarding tonnage and value of the ore should be raised. The main object of making an estimate of this kind, is to have some means of judging how much money should be spent in developing the prospect.

The tonnage factor, or number of cubic feet of ore in place, not broken, required to weigh one ton, varies with the kind of deposit. Gold bearing quartz veins range from 12 to 15 cubic ft per ton, with 13 or 14 cubic feet as a common figure. Ores containing lead or iron may range from 7 to 10 cubic feet per ton. The only safe procedure is to determine the specific gravity of the material rather than to guess at it. If a measured volume can be cut out and weighed, the weight per cubic foot is directly obtained. Where it is not convenient to do this, several lumps, as large as one's first, and which are good average specimens of the material, can be used. The specific gravity of each piece should be found by the method given below and the average of the results taken for the calculation of tonnage factor. First weigh in the air, suspending the lump from the beam of the balance by means of a thread, horse hair or a very fine wire, whose weight is negligible. Then weigh the lump when fully immersed in water. For the most accurate results the water should be distilled, rain water is good, and should be at a temperature of 60° F. Let W be weight in air and W′ the weight in water, then

$$\text{Specific gravity} = \frac{W}{W - W'} \qquad \text{(Formula 3)}$$

The specific gravity of small pieces can be determined by the bottle method. The pieces are crushed to a powder, which should be thoroughly dry. Then a bottle, of such a size that the powder would fill it half or two-thirds full, is filled to the top, or to a mark scratched on the neck, with pure water at 60° F., and the weight noted. Call this weight W′. Now weigh the dry powder in air, calling this weight W. Empty the bottle and pour in the powder, then fill with water to the original mark and weigh. This weight is W″.

$$\text{Specific gravity} = \frac{W}{(W + W') - W''} \qquad \text{(Formula 4)}$$

The powder should first be boiled for fifteen or twenty minutes in water and then cooled before it is placed in the bottle. This is to insure the elimination of air bubbles that would stick to the ore if it is covered with cold water. It is a difficult matter to thoroughly wet dry powdered ore.

A suitable balance is not always available. However, it is an easy matter to construct a specific gravity balance that will be satisfactory. A sketch of such balance is shown in **Figure 11,** and its construction and operation will now be explained. The beam is a piece of wood ¼ to ⅜ inch thick, ¾ to 1 inch wide and about 36 inches long. A yardstick does very well, and has the advantage of already being divided into inches, but the beam can be fashioned from any convenient board. A small nail, 6d finish, or wire is heated in the fire and two holes are burned through the beam, one about an inch from the end and the other just 10 inches from the first. This distance is measured from center to center of the holes. Beginning at a point 10 inches from this second hole, a scratch is made on the side of the beam. A second scratch is made 10 inches from the first. These points are marked 1 and 2 as shown in the illustration. The distance between them is divided into tenths (inches) and marked 1.1, 1.2, 1.3, etc. The marks are best made with a knife blade and then blackened with a pencil. More exact measurements can be made in this way.

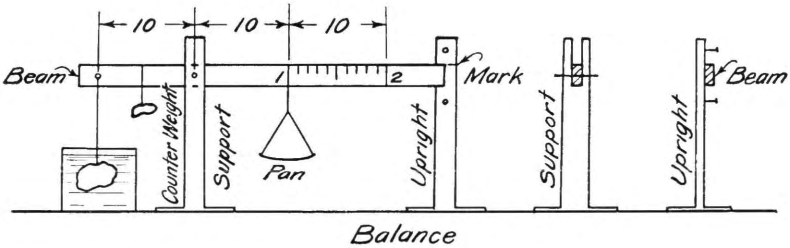


Figure 11

Two nails slightly smaller than the holes in the beam are selected. One is used for mounting the beam on the support, the other is put through the hole near the end of the beam and a wire loop is attached to it. The support may be a single stick with a notch cut in the end, or two thin pieces may have another piece, slightly wider than the beam, put between them as a spacer. An upright is placed at the end of the beam. Two nails are driven into the upright about 1 inch from the beam. These serve as stops when adjustments are being made. The beam should be carefully leveled and a horizontal mark made on the upright just even with the top of the beam. All weighings are made to this mark. For a pan to hold weights, a piece of tin 3 or 4 inches in diameter is suspended from the beam by a loop of thread. As soon as this form has been made it is placed at figure 2 on the beam. Before using the beam should be balanced, that is, brought to the horizontal position, by a counterweight placed on the short arm. A small piece of rock tied to a thread will answer the purpose. This is moved back and forth until the position of balance is found. The apparatus is now ready for weighing. The lump of ore is suspended from the loop of wire by means of a thread. The weight pan has already been placed at figure 2 on the beam and weights are now added until the beam is brought to the horizontal position. Nails, pieces of rock, or even dirt may be used as weights. The actual weight does not matter, since the whole operation depends upon relative weights only. The beam is quite sensitive and the weights must be added very carefully. A dish of water is now placed under the short arm so that the ore is entirely under water but does not touch any part of the dish. Without disturbing any of the weights, the weigh pan is moved along the beam toward figure 1, until the beam is again in balance. This point is now read on the scale. Since the relative weights both in air and water are now known, the specific gravity can be calculated by formula 3. Thus, if the second reading is 1.14 (the last decimal place can be estimated by the eye), since first is always 2, the specific gravity $= \frac{2}{2 - 1.14} = 2.32$. A ton of water has a volume of 32 cubic feet, consequently the tonnage factor is found by dividing 32 by the specific gravity. In this case the tonnage factor is $32 \div 2.32 = 13.8$, the number of cubic feet in a ton. When constructing the balance, all measurements should be very carefully made. Both nails should turn freely in the holes, and the beam should not bind against any part of the support or the upright. When making the second weighing, the one with the lump under water, the slightest movement of the thread of the weight pan along the beam greatly changes the balance of the apparatus. Some ores may be porous and absorb a large quantity of water. If ore of this kind is to be tested, the lumps should first be dipped in shellac or melted paraffine before making the weighings. For pieces of the size mentioned, the additional weight of this waterproof coating will not seriously affect the accuracy of the result.

It is possible to construct the balance so that the calculations can be omitted and the tonnage factor read directly from the beam. In order to do this the beam must be graduated as directed above, but the marks should read according to the list given below.

1	should	be	marked	16.0
1.1	"	"	"	14.5
1.2	"	"	"	12.8
1.3	"	"	"	11.2
1.4	"	"	"	9.6
1.5	"	"	"	8.0
1.6	"	"	"	6.4
1.7	"	"	"	4.8

The marks 1.8 and 1.9 can be omitted since they are below the range of any ores likely to be tested, and the last point is marked 2 as before.

The balance is used in the same way as described before. After balancing with the empty pan at the mark 2, the lump of ore is suspended from the loop of wire and weights are added to the pan until the beam is again in balance. The ore is now placed under water, and the pan with its weight is moved back along the scale until the beam is once more in balance. The reading at this point shows directly the number of cubic feet of the ore required to weigh one ton.

SAMPLING DUMPS AND TAILING PILES

The tonnage factor or number of cubic feet of the material in one ton may be fairly closely determined by filling a small box of one or two cubic feet capacity with the material, packing it as closely as it occurs in the dump or pile, and carefully leveling off the box, which is then weighed. By subtracting the weight of the empty box the net weight of the material per cubic foot is determined.

For tailings containing considerable water several small samples, about a pound each, should be taken, carefully weighed and then dried for several hours at a temperature a little above the boiling point of water. After a sample has been dried, it should be cooled in a dry place and then weighed. It should then be put back in the drier again for another period, then cooled and weighed again. If the two weighings agree the sample is dry, but if the second weighing is less than the first, the drying should be continued with the dried weight is constant.

Suppose the undried sample weighed 14 ounces and the sample after drying weighed 11 ounces, then the weight of dry tailings in the original sample is $11 \div 14 = .786$ or 78.6 per cent. If weighing the material in the box gave a tonnage factor of 16 cubic feet to the ton, the number of cubic feet of the material required to give one dry ton would be $16 \div .786 = 21.6$ cubic feet as the true tonnage factor.

To sample a small dump that is relatively long and narrow, trenches may be cut at right angles to the long axis of the dump. These should be cut across the dump and should be parallel to each other, spaced from say 20 to 50 feet apart, depending upon the length of the dump. For large dumps small shafts about 30 inches in diameter may be sunk to the bottom. The material from each 5-foot section may be coned and reduced to sample size by quartering. Large pieces should be crushed or broken before the sample is reduced in size.

A tailing pile may be sampled by boring holes with a post auger having fastened to it a 15 or 18-inch piece of stove pipe or sheet iron bent into cylindrical form and covered. The several borings making up a 5-foot section of the hole should be well mixed together before being reduced in bulk to a final sample. The holes should be spaced regularly at a uniform distance apart, say from 50 to 100 feet.

The dump or pile should be surveyed or measured in such a way with a steel tape that its volume can be calculated and its tonnage determined by dividing the volume by the tonnage factor.

The amount of hard and careful work needed to correctly sample a mine or large dump is not ordinarily understood, but unless it is conscientiously done little reliance can be placed on the result.

THE COMMERCIAL VALUE OF ORES

Up to this point reference to the value of ores has been avoided as much as possible. Assay reports have been regarded as figures which show the mineral content of the ore rather than its value, because value is an indefinite term when used by itself. It might mean "gross" or it might refer to "net value." Gross value is the total combined value of all metals in the ore. The assays are multiplied by the market price of the metal and these products are then added together. This gross value is the value that the owner of a prospect usually places on his ore. Net value if shipped to a custom plant is the actual amount received for the ore after deducting:

(a) Transportation charges from mine to mill or smelter.

(b) Deduction for metal losses in milling or smelting or both.

(c) Charges for milling or smelting or both.

(d) Deductions for transporting recovered metals to the refinery.

(e) Refining charges.

(f) Transporting refined metals to points of sale.

(g) Selling expense.

It is the gross value less the cost of mining, transportation and and treatment. Thus, the gross value of an ore may be $75 per ton, and yet the net value may be only $20.00 per ton. When the ore is shipped to a smelter and the shipper receives only a small part of the gross value that he has figured his ore to have he naturally feels that he is not being fairly treated. The reasons for the differences between gross and net value will now be discussed.

In the first place, mills, smelters, and other metallurgical plants, though using the most modern methods of treatment, fail to make a complete recovery of the metals in ores. Some idea of the magnitude of these losses may be had from the following figures. Losses in milling complex lead-zinc ore by flotation: Gold, 5% to 30%; copper 10% to 30%; lead, 5% to 20%; zinc, 10% to 25%; losses in milling sulfide copper ores by flotation: Gold, 5% to 20%; silver, 5% to 30%; copper, 5% to 20%; losses in milling oxidized copper ores by flotation: Gold, 10% to 50%; silver, 10% to 50%; copper, 10% to 25%; losses in leaching oxidized copper ore: Copper, 5% to 25%; losses in cyaniding gold and silver ore: Gold, 5% to 25%; losses in smelting when smelting in a lead blast furnace: Gold, 1% to 5%; silver, 1% to 5%; copper, 10% to 25%; lead, 5% to 10%; losses in smelting in a copper reverberatory furnace: Gold, 3% to 10%; silver, 3% to 10%; lead approximately 50% is recovered in the form of Cottrell treater dust and flue dust.

In the second place, ores commonly contain some deleterious or harmful minerals, which not only render treatment difficult but which may increase the loss of the valuable metals. Such minerals may be of little or no value in themselves or they may be some of the metal bearing minerals. A high silica content means that the ore will be hard to smelt, and that the addition of some other minerals, or flux as it is called, is necessary for satisfactory smelting. The treatment of copper and lead ores is made troublesome by the presence of zinc, which makes a thick sticky slag resulting in relatively high metal losses unless additional iron is added. In these cases, not only is no payment made for the zinc, but penalties imposed for all zinc present in excess of (usually 6%) to cover the cost of the increased consumption of iron. Smelters base their settlements on a system of bonuses and penalties. When any constituents of the ore, have a beneficial effect on the smelting process an additional payment or bonus is usually given for these minerals. On the other hand, charges or penalties are imposed on any constituents that render smelting more difficult. Silica, alumina, zinc in ores of other metals, antimony, tin, arsenic, bismuth, sulphur, etc., when present in quantities above a certain fixed limit are generally penalized, while iron manganese and lime are usually paid for.

Smelter contracts make frequent use of the word "unit." Ores are paid for at so much per unit of a certain metal, or a penalty of so much per unit is imposed on some deleterious constituent. A unit means 1 per cent. Since a ton contains 2,000 pounds a unit is equivalent to 20 pounds for every ton of ore. The statement that manganese will be paid for at the rate of $1 per unit, means that $1 will be paid for each per cent, or each 20 pounds, of manganese in a ton of ore. A penalty of 10 cents per unit of zinc means that an additional charge will be made for each per cent of zinc in the ore. A more detailed study of some smelter contracts will be made below.

A point that is of interest in the case of some ores might be called the minimum content requirement. The purchase of manganese, tungsten, molybdenum and iron ores and concentrates is based on a certain minimum metallic content that the material for sale must have. As taken from the mine the ore may be too low in grade to meet this requirement. This means that the ore must be concentrated in order to obtain a salable product. Another condition should be mentioned. All ores are not rated on a straight metallic content.

Copper, lead and zinc ores are paid for at so much per pound of metal, but tungsten and molybdenum ores have their value based on their content of tungstic trioxide (chemical formula WO_3) and molybdenite, or sulphide of molybdenum (chemical formula MoS_2) respectively. There is no valid reason for using a chemical compound in place of the metal, but the custom is well established and must be recognized no matter how confusing it may be. Manganese ores are unusually required to contain at least 38 per cent manganese, tungsten settlements are based upon a 60 per cent WO_3 content, molybdenum ores are sold on a basis of 90 per cent MoS_2, and iron ores must contain 25 per cent or more of iron, though this requirement varies with the kind of ore and the deleterious minerals present. Suppose it is desired to know what a 63 per cent WO_3 concentrate is worth, the market price being $26 per unit for 60 per cent WO_3 material? This means that the material, in order to receive the price of $26 for each unit of WO_3 present, must contain at least 60 per cent or 60 units of WO_3. Since this requirement is more than fulfilled, the total value is the number of units present times the price per unit or 63×$26=$1638 per ton.

Moisture in ore is another important item, especially in regard to its bearing on transportation charges. Smelter settlements are based on dry ore, but freight to the smelter must be paid by the shipper on the water in the ore as well as on the ore itself. At one prospect, the wagon haul to the railroad cost $4.00 per ton and the freight to the smelter was $2.50 a ton, making a total transportation charge of $6.50 per ton. A carload lot of 40 tons was shipped to the smelter and was found to contain 20 per cent moisture. Now 20 per cent of 40 tons is 8 tons, and, at $6.50 a ton, the cost of sending this water to the smelter was $52. True, it is not always feasible or even desirable to thoroughly dry ores before shipping, but a little attention paid to the question of moisture may save the needless expenditure of many dollars. Hauling in rainy weather might be avoided as much as possible, or the ore could be covered by a piece of canvas. Ore bins or storage platforms could be roofed over at no great expense, and the ore could be loaded in closed cars. Very fine dry ore, would suffer a heavy loss from dusting if loaded and unloaded in a heavy wind. Where the ore comes from a very wet mine, it might prove economical to pass the ore through some sort of a dryer before shipping.

The following contracts are given to illustrate the methods of determining the value of an ore from its assay. A specific smelter contract would differ slightly from those given in some points but not very greatly.

DIRECT SMELTING LEAD ORES

Lead: Must contain 5 per cent or more of lead by wet assay. Deduct 1.5 units from the wet assay to arrive at the settlement assay. Pay for 90 per cent of the settlement assay at New York price, less 1.65 cents per pound.

Gold: Pay $19.00 per ounce for all gold 0.02 ounces per ton or more.

Silver: Pay for 95 per cent at New York price if 1 ounce or over.

Copper: Deduct from wet assay for copper 0.75 units or 15 pounds and pay for 100 per cent of the remainder at the daily New York quotation for electrolytic cathodes less 6 cents per pound.

Iron: Pay for all at 6 cents per unit.

Deductions

Insoluble: All at 10 cents per unit.

Zinc: Free up to 7 per cent, above this charge 30 cents per unit.

Sulphur: Free up to 2 per cent, above this charge 25 cents per unit up to a maximum of $2.50 per ton.

Arsenic—Antimony: 1 per cent free, all over 1 per cent at 50 cents per unit.

Smelting charge is $2.00 to $3.00 base for ore containing 30 per cent lead by settlement assay. A 10 cent credit or deduction is made for each per cent of lead above or below 30 per cent.

Explanation: An assay for lead may be made by either of two methods. One is the fire assay, in which the sample is mixed with fluxes, placed in a small crucible and smelted in the assay furnace. This method is supposed to represent actual smelting conditions, and the lead is obtained as metal in a small button, called a fire button. A small amount of impurities is generally present. The other is the wet assay, in which the lead is determined by chemical analysis. No metallic lead is obtained, but the method gives accurately the amount of lead in the ore. Except in a few cases, the fire assay gives a lower result than the wet assay, the difference being from 1 to 2 per cent. According to the contract, the ore is assayed by the wet method to get its actual lead content and 1.5 per cent is deducted to give the equivalent of a fire assay. Then 90 per cent of this figure is used as the basis for settlement. The lead is not paid for at full market price, but at a figure 1.65 cents a pound lower. This charge is to cover the cost of refining and marketing, and freight to the refinery.

Silver is not paid for unless 1 ounce or more is present. Payment, when made, is for the full silver content, as shown by assay, but the price received is only 95 per cent of the market quotation.

Gold is not paid for unless 0.02 ounce or more is present. Payment for gold is made at $19 per ounce. Since gold is worth $20.67 per ounce this amounts to a deduction of about 8 per cent of the gold content of the ore.

Copper is not paid for unless the ore carries 0.75 units or 15 pounds per ton or over. Settlement is made at 6 cents a pound less than the market quotation. This deduction is to cover all losses during treatment and the cost of refining and marketing and freight.

Insoluble. (Sometimes called silica.) Silica makes a thick slag that must be fluxed with iron or lime, if the furnace is to operate properly. The terms insoluble and silica are often used interchangeably, but they are different things. Silica is determined by a special fusion assay. Insoluble is the residue left after the ore has been digested with acids in the course of assaying for some of the metals. The insoluble is generally silica plus something else, often alumina, since this substance is not always dissolved by acids. According to the contract, for each unit of insoluble present a penalty of 10 cents is imposed.

Sulphur is penalized, if more than 2 per cent is present, at the rate of 25 cents per unit until the total charge reaches $2.50, when no further penalty is imposed. This point would correspond to 12 per cent sulphur, since 2 per cent is allowed free. When an ore contains more than a small amount of sulphur, the sulphur content must be reduced by roasting. The charge is to cover the cost of roasting. Sulphur is a fuel and will burn, but, where present in small quantity, some outside fuel must be used to heat the ore. For ores of high sulphur content, the sulphur acts as a fuel after it has been set to burning. Zinc is not penalized unless more than 7 per cent is present, in which case a charge of 30 cents is made for each unit over 7. Some of the zinc goes into the slag making it pasty and increasing the metal loss in the slag. Part of the zinc is volatilizied and condenses to form accretions or hard masses inside the furnace top, which may reach such a size as to seriously obstruct the passage of the hot gases. They are very hard to loosen from place.

Arsenic unites with lead, iron and copper to form a substance called speiss. Arsenic may also go into the lead bullion, making it hard and costly to refine. Antimony behaves in somewhat the same way. For these metals all over a combined 1 per cent is charged for at 50 cents per unit.

The treatment charge is $2.50 per ton for an ore containing 30 per cent lead. This is called the basic treatment charge, and variations are figured up or down from this point. For every unit of lead in the ore above 30 per cent, the charge is decreased 10 cents per ton. An increase of 10 cents per ton is made for every unit below 30 per cent.

When calculating the value of an ore, the various constituents which are listed in the smelter contract should be gone over one by one and classified as a credit or a debit. The total credits less the total debits represent the amount the smelter will pay for the ore.

LEAD ZINC CONCENTRATING ORES

Some ores can be concentrated more easily than others so that no uniform schedule is made for all concentrating ores. Each ore is considered as a special case by itself.

Gold is generally paid for at $17 an ounce if over 0.01 ounce. If the loss of gold in concentrating is high a lower price may be paid.

Silver is generally paid for at 90 per cent of the assay less 3.5 cents an ounce if over one ounce. In ores hard to concentrate only 70 per cent of the silver may be paid for.

Lead and Copper. Treat the copper as lead and add it to the lead content. If the combined lead and copper amounts to 4 per cent or over they are paid for on the basis of 80 per cent of the content as shown by wet assay at the average New York price for the week less 3.8 cents per pound.

If the ore contains over 10 per cent combined lead and copper, the price paid is increased by 0.05 cent a pound for each 1 per cent over 10 per cent up to a total increase of 0.5 cent per pound. Also the content paid for is increased above 80 per cent by 1 per cent for each unit over 10 per cent up to a total of 90 per cent. Thus a 7 per cent combined lead and copper content, with lead selling at 5.5 cents a pound has the following value: 80 per cent of 7 per cent = 5.6 per cent or 112 pounds per ton, and the price paid is 5.5—3.8=1.7 cents per pound. If the ore contained 15 per cent combined lead and zinc 85 per cent of the content would be paid for at 1.7+.25=1.95 cents a pound.

Zinc is paid for on the basis of 60 per cent of the zinc content if 4 per cent or over at the market price of Prime Western zinc in St. Louis less 2.875 cents a pound when the price of zinc is 4 cents a pound or less. Certain additions are made if the price of zinc is above 4 cents a pound.

Treatment charge ranges from $3.00 to $5.50 a ton, depending upon the nature of the ore.

Copper Ores

Smelter contracts for copper ores are quite similar to those for lead ore. However, the deductions for straight copper ores are somewhat less than for copper in lead ores due to the fact that the matte (combination of sulphur with iron, lead and copper) formed in lead smelting is more costly to treat than the matter from copper smelting which contains no lead.

In general, for copper ores a deduction of .75 unit or 15 pounds of copper is made from the assay content of the ore, and 100 per cent of the remaining copper is paid for at market price less 3 cents a pound. The treatment charge is much the same as for lead ores.

Zinc Ores

Schedules for zinc ores are variable in nature and are commonly based on a high minimum content of zinc that virtually requires an ore to be concentrated before going to the smelter.

Selling Ores

In regard to selling ores, the matter should be taken up directly with the smelters and ore purchasing companies. A proposed contract should be studied and the price to be paid for the ore should be calculated. This is the only way in which different contracts can be compared. A smelter may be in need of a particular type of ore, and for this reason may give slightly better terms than are customarily offered. Gold and silver ores can be sold to copper and lead smelters. Freight to the smelter is paid by the seller. Railroads have a sliding scale of rates, and high grade ores are charged a somewhat greater freight rate than is paid on low grade ores.

CONCLUSION

This Bulletin has not been written for the practicing mining engineer. It is a primer by means of which those, unacquainted with the business of mining, can gain a knowledge of the elementary principles involved in estimating tonnage and valuing ore. Figures given are sometimes compromises between two extremes, because a detailed discussion of the points involved would require too much space and might confuse the reader. Nevertheless, the information given should enable a prospector to take samples that are fairly representative of a deposit instead of the usual grab samples which are misleading, and, therefore are worse than none.

A mineral discovery to be of commercial value must contain ore in sufficient quantity and of such a grade that its net, not gross value, makes the deposit worth exploiting. The cost of mining may range from $4 to $12 a ton, or even higher for a prospect far from a railroad, and freight may cost nearly as much. Narrow veins cannot usually be worked without breaking down more or less wall rock, which increases the cost of mining the vein besides lowering the grade of the ore, since it is seldom possible to sort out all waste rock. It is poor business to spend time and money in driving a long adit to cut a vein some distance below the surface. The vein, because of faulting or pinching out, may not be found, and the same effort put into following the vein down from the surface will do much more toward proving the worth of the deposit.

PURCHASERS OF COPPER ORES

Garfield Smelting Company, Garfield, Utah.

International Smelting & Refining Company, Tooele, Utah.

PURCHASERS OF LEAD ORES

American Smelting & Refining Co., Murray, Utah.

United States Smelting, Refining & Mining Co., Midvale, Utah.

International Smelting & Refining Co., Tooele, Utah.

Selby Smelting & Leading Company, Selby, California.

PURCHASERS OF ZINC ORES

International Smelting Co., Salt Lake City, Utah.

American Smelting & Refining Co., Amarillo, Texas.

Ozark Mining & Smelting Co., Caffeyville, Kansas.

International Minerals & Metals Corporation, 11 Broadway, New York City.

Bunkerhill & Sullivan Mining Co., Kellogg, Idaho.

For those who wish to gain a more extensive knowledge of mine sampling, a list of useful reference books is given below. Some information contained in these books is included in this Bulletin.

Sampling and Estimating Ore in a Mine. T. A. Rickard. Price $2.00.

Prospecting, Locating and Valuing Mines. R. H. Stretch. Price $2.50.

The Principles of Mining. H. C. Hoover. Price $2.50.