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HANDBOOK FOR SMALL MINING ENTERPRISES

by

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HANDBOOK FOR

SMALL MINING ENTERPRISES

Prepared for MONTANA BUREAU OF MINES AND GEOLOGY

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U. S. BUREAU OF MINES

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PREFACE TO THE REVISED EDITION

The present work is an outgrowth and revision of the 'Handbook for Small Mining Enterprises in Montana', which was published jointly by the Montana Bureau of Mines and Geology and the Federal Small Business Administration in 1964. In time, the original Handbook achieved broad circulation in the mining community and elicited much favorable comment. As a result, it was felt that a revised edition, eliminating provincial aspects of the original that restricted its application to Montana deposits, would be well received.

The revision of the Handbook has encompassed many areas. Some errors in the original manuscript came to light after publication. More importantly, many aspects of the industry have changed in the last decade; new procedures have evolved, new technology has been developed, and the cumulative effect of another ten years of continuous inflation has left its mark on the economics of the mining industry. Other significant events include the release of gold from more than 40 years of stifling government control, and the birth and development of environmental awareness with its myriad, and often complicated, effects upon both the producer and the consumer of raw materials.

Like its predecessor, the revised Handbook is a cooperative effort. Principal financing has been provided by the U. S. Bureau of Mines, with contributions by the Montana College of Mineral Science and Technology Foundation and by the Montana Bureau of Mines and Geology. Again, the effort has been to present concepts and procedures in the most simple and straightforward manner possible. The Handbook is intended to serve those who have the advantage of considerable technical training and those who have had little or none.

The Authors

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CHAPTER 1 — GEOLOGY FOR THE SMALL MINE

By

F. N. EARLL

INTRODUCTION

If one thing can be said to be common to virtually all small mining operations it would be the almost universal lack of a geologic department to advise management on matters relating to exploration, development, and mining. It can only be concluded that most small-mine operators believe that the management of all large mining companies the world over suffer from some virulent form of contagious stupidity. Why else would they invest so many of their hard-earned dollars in the maintenance of large and well-integrated geological departments. Yet, through some odd quirk of fate, these same large companies consistently show profits of millions of dollars every year from ores that are frequently of such low grade that most small-mine operators would not consider mining them. Of course the economies that are alleged to be 'inherent' in large-scale operations play a part in their success, but it is also true that these economies are more often earned than inherited. It is also just possible that the investment made by these companies in geology has not been entirely wasted.

Geology, for the operating mine, can be conveniently separated into two stages: mapping and interpretation. The mapping phase is of considerable importance in its own right, providing as it does the base upon which current ore reserves must be calculated and new ore blocks developed, and providing information relating to the proper location of mine workings and allowing anticipation of some of the various forms of grief that may confront the operator. The second phase, interpretation, is truly the life blood of a continuing operation. Few of us would dream of attempting to drive an automobile down a highway while wearing a blindfold, yet many a mine operator thinks nothing of conducting his exploration with an equal handicap. Although the analogy may seem somewhat gruesome, the two procedures enjoy roughly the same chance of success.

At this point the reader may be thinking that he cannot afford to keep one or more geologists on the payroll. That is the purpose of this manual: to provide information so that the small-mine operator can perform many of the duties of the geologist himself. On the other hand, there are many operators who really could afford a geologist-engineer, and those who can would do themselves a service if they hired one, if for no other reason than that it would relieve them of the burden of acting in his stead. Those who elect to be their own geologist will find that with reasonable effort they can do a very creditable job on the routine work of the mines geologist. It need not consume an inordinate proportion of their time. For most small mines one day every two weeks, or better one afternoon each week should be sufficient. With practice you will find that you can either accomplish much more in the allotted time, or devote less time to the work. An equal amount of time should be allotted for necessary office work related to geology. In the larger 'small' mines it may prove necessary to devote a part of every day to geological mapping, but operators of such mines could and should hire a resident geologist-engineer.

Even those who elect to do their own geology may find it advantageous to call upon a consultant at regular intervals to aid in the interpretation of the broad picture. In order to gain real benefit from the consultant's experience, however, you must provide him with the basic tools, which include reasonably accurate maps and sections. It is an old and familiar story to the consultant to be called upon to advise on exploration only to find that the evidence needed has long since been shipped to the mill, if, indeed, the workings are accessible at all. In these cases the best that he can offer is the recommendation of a broad drilling or crosscutting program in the hope that evidence will be forthcoming that will allow an intelligent analysis of the situation. Don't blindfold your consultant; after all, he is charging you for his time.

The discussion to follow has, for convenience, been presented in two sections: Geology for underground mines, and geology for open-pit operations. Although these two types of operation have much in common, the purely mechanical differences indicate that they can best be considered separately.

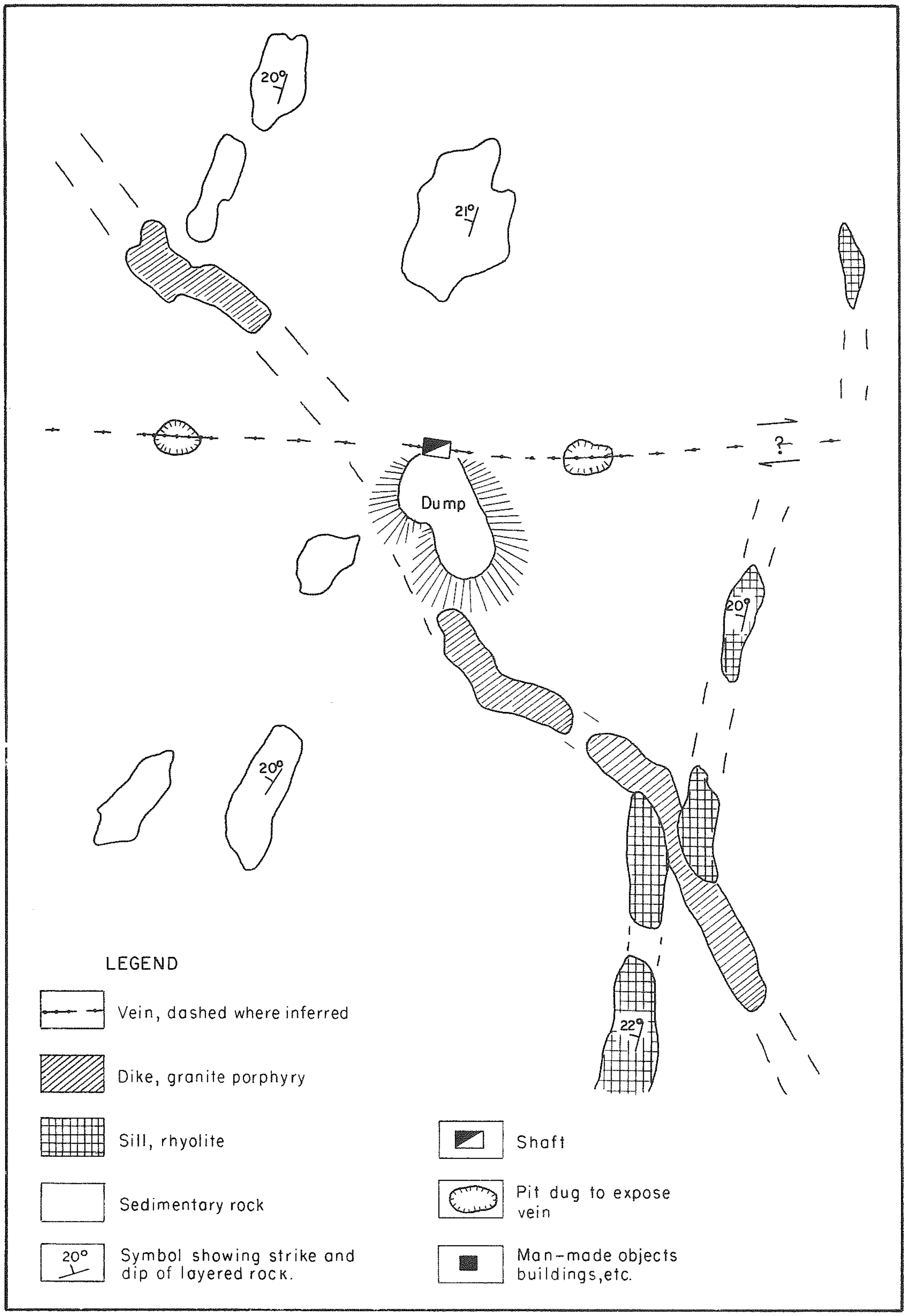

FIGURE 1-1.—Outcrop map showing interpretation.

GEOLOGIC MAPPING FOR THE UNDERGROUND MINE

The geologic map requirements of the underground mine are surface maps and underground maps. Of the two, the underground maps are of greater immediate benefit to the operator. Surface mapping should not be forgotten, but the do-it-yourself geologist would do well to subcontract this phase of the operation to a professional geologist, if possible. For one thing, the surface mapping should be at least semiregional, taking in at least the entire district as well as such surrounding areas as may be related to local structures and mineralization. Then, too, it is one thing to plot geology that is beautifully exposed in underground workings, and quite another to decipher it from evidence that is partly covered by vegetation and soil, particularly as rocks exposed at the surface can be expected to have undergone varying degrees of weathering and erosion that tend to make them well-nigh unrecognizable to the neophyte.

If you elect to prepare a surface map for yourself, the methods for plotting the locations of mine openings, as described in the following paragraphs, can be used to locate other features of geological interest as well. The professional geologist usually maps at surface by the 'outcrop method', plotting only those areas of actual exposure or 'outcrop' of the bedrock on his map. Then, after all outcrops have been mapped, he will attempt to put the accumulated information together into a complete picture. However, this final step of filling in the blank spaces where outcrops are lacking should always be done using dashed or dotted lines or some other suitable device to indicate the uncertainty of the interpretation. Figure 1-1 illustrates the sort of map that might result.

The first requisite for underground mapping is a set of reasonably accurate plans of existing workings. The most desirable instrument for this purpose is a mine transit, but such instruments are expensive and, unless used by a trained person, may lead to more confusion than benefit. At this point it might be worth mentioning that a competent surveyor with one or two helpers could survey the workings of the average small mine with adequate accuracy in two to four days. The small investment necessary to have this done might well be worthwhile, and those operators who prefer to follow the simplified methods described in the following paragraphs may find it advantageous to call in a surveyor once a year to locate such control points as may be necessary to make minor corrections on existing maps.

The first step in the mapping operation is to establish a starting point. In a mine developed by one or more adits or tunnels, the location of a portal is the starting point. Although it is desirable that its absolute geographic position be known, the location can be assumed or approximated without serious consequence. Where there are two or more surface openings, their position relative to each other must be accurately known. A compass and tap measure can be used to locate surface openings, and they will prove invaluable later for underground work. A compass of the type known as a Brunton compass or Brunton pocket transit is most desirable for this purpose because: (1) it can be read accurately to one-half degree; (2) it has an extended sight that allows much more accurate sighting than the ordinary compass; and (3) it has an additional attachment (clinometer) that permits measurement of vertical as well as horizontal angles. The tape should be 100 feet

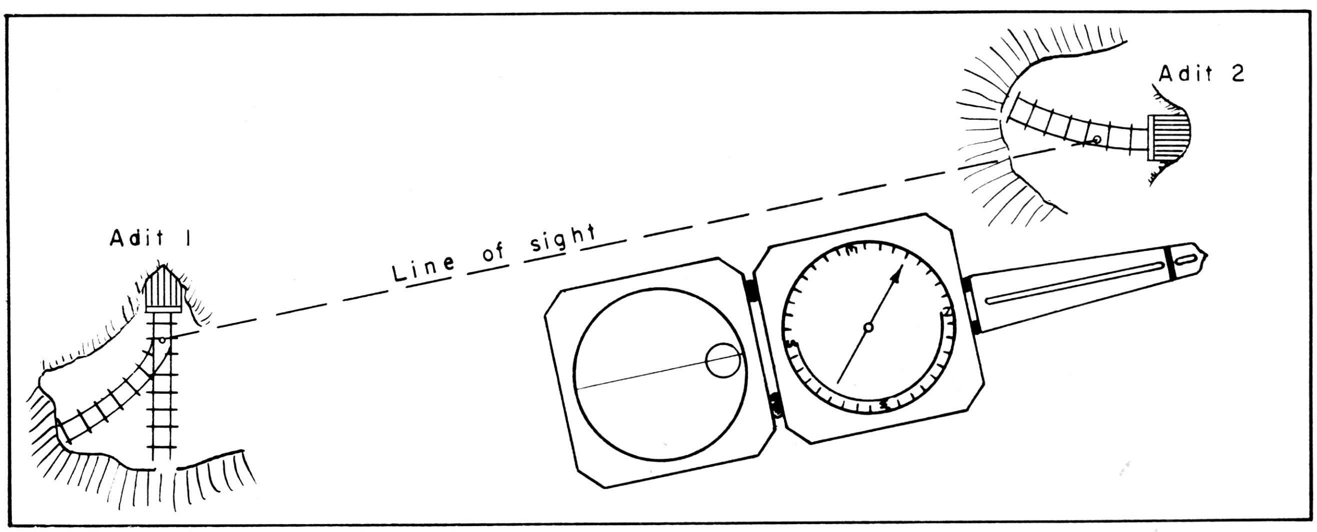

FIGURE 1-2.—Use of Brunton compass for horizontal bearing. The compass is sighted from a point on the dump of adit 1 to some object on the dump of adit 2. The compass needle points 50° east of north, or as commonly stated, N.50°E.

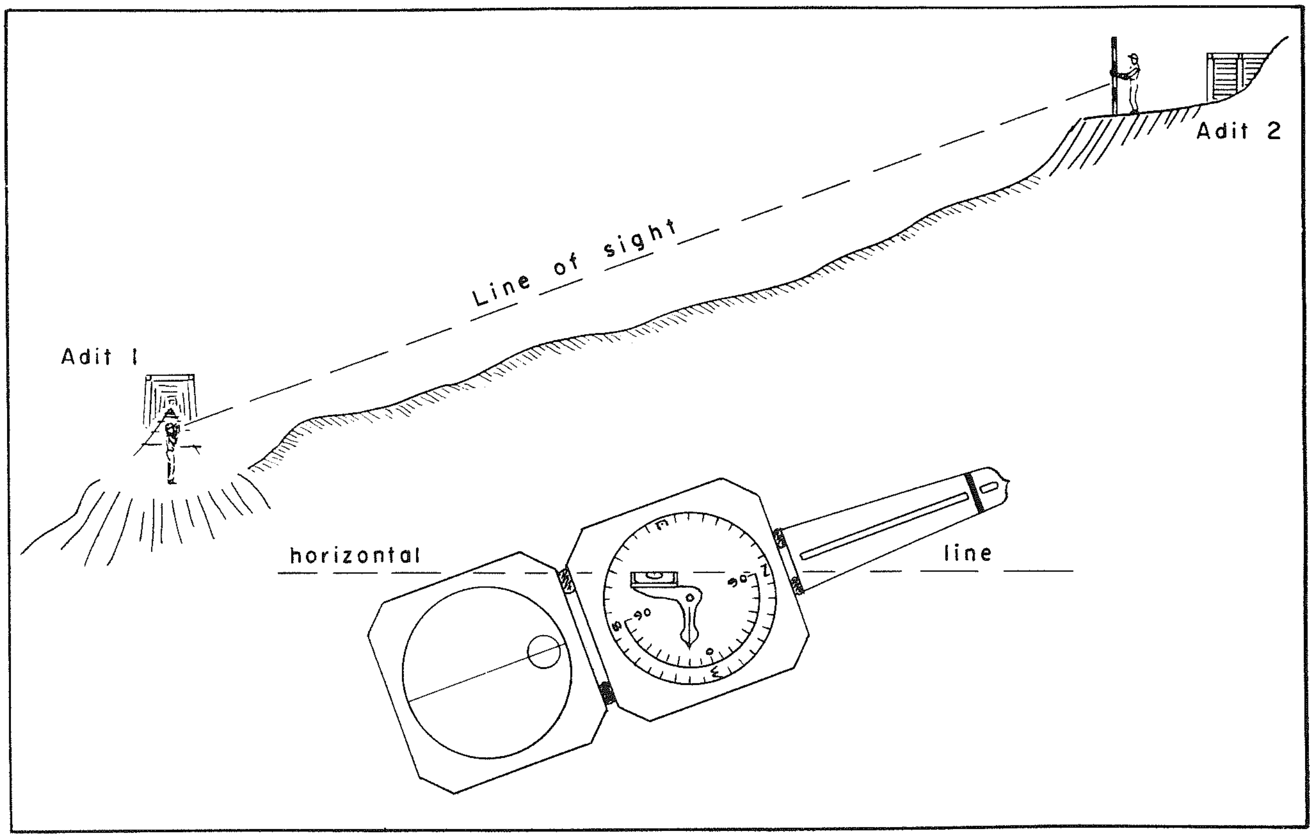

FIGURE 1-3.—Use of Brunton compass for vertical angles. The compass, used as a clinometer, is sighted at a helper standing on the dump at adit 2. The clinometer bubble is leveled, and the pointer shows that the sight is 20° above the horizontal.

long, the glass-fiber or wire-backed cloth type that rolls into a case being excellent. A small all-brass tripod that holds the compass steady and allows somewhat more accurate work can be purchased at extra cost. Professionals, however, generally disdain the tripod, and with practice the difference in accuracy of the tripod-held instrument and one held by hand becomes less and less. Many camera tripods contain steel parts that make them unsuitable for Brunton work because of the magnetic attraction of steel.

A compass points to magnetic north, which for most locations is several degrees from true north. The difference becomes important when you want to establish the location of mining property with relation to other known points, for example, when you are attempting to relocate the boundaries of old claims or other real property. The amount of difference between true north and the direction in which a compass needle will point is called the magnetic declination, and is zero along a line that extends roughly from Lake Michigan to the northeast corner of Florida. East of this line the compass will point west of true north, the amount increasing with distance from the zero line; it is as much as 23 degrees in the northeastern corner of Maine. West of the zero line the compass points east of true north, the amount again increasing with distance, so that at Puget Sound the declination is 23 degrees east. The declination for any point in the United States can be determined from charts published by the U.S. Coast and Geodetic Survey, from published topographic maps of the area of interest, or from tables in any surveying text. The Brunton compass can be made to correct for magnetic declination by rotating the compass card by means of a small tangent screw on the side of the instrument case.

For site mapping, however, only the relative position of two or more points is of concern. Therefore, the difference between true north and magnetic north can be ignored. The procedure for locating two points on the surface is: (1) choose one point that is to be located at some arbitrary point on the map (chosen so that most of the workings will be located on the map sheet); (2) sight the compass at the second point, preferably at a helper holding a rod upright but any visible object will suffice, being careful to hold the compass level; (3) read the compass dial to determine direction to the second point (see Fig. 1-2 for detail).

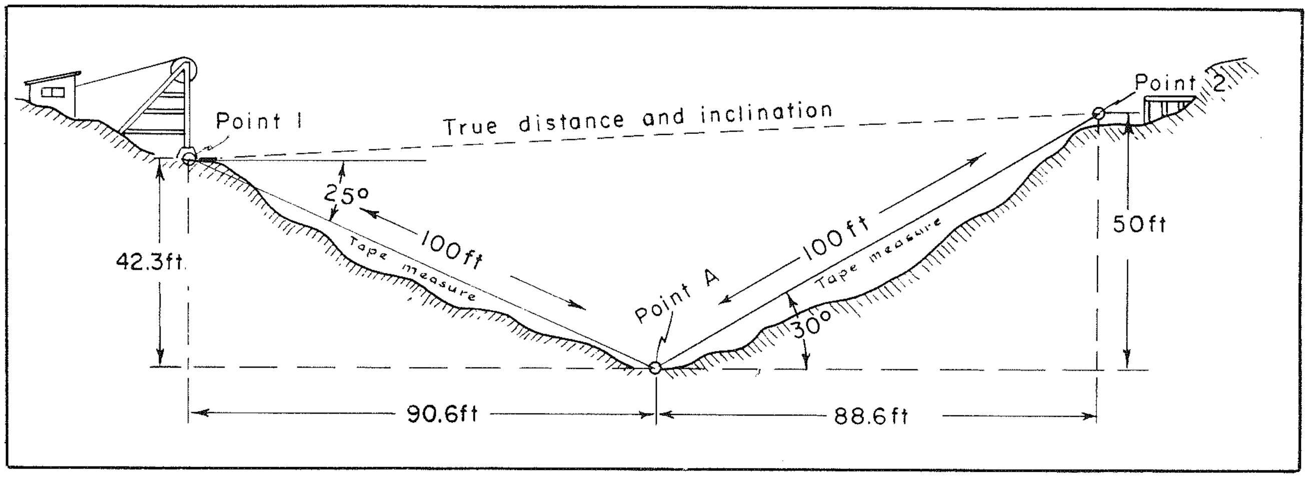

FIGURE 1-4.—Sketch illustrating vertical height calculation. The tape is stretched from point 1 (shaft) to a point A at the bottom of the draw separating the two points, the inclination from point 1 to point A being —25°. The tape is then stretched from point A to point 2, the inclination from point A to point 2, in this case, is +30°.

TABLE 1-1.—Natural sines and cosines of angles.

Angle	Sine	Cos.	Angle	Sine	Cos.	Angle	Sine	Cos.
0°	.000	1.0000	30	,500	.866	60	.866	.500
1	.017	.9998	31	.515	.857	61	.875	.485
2	.035	.9994	32	.530	.848	62	.883	.469
3	.052	.999	33	.545	.839	63	.891	.454
4	.070	.998	34	.559	.829	64	.899	.438
5	.087	.996	35	.574	.819	65	.906	.423
6	.105	.995	36	.588	.809	66	.914	.407
7	.122	.993	37	.602	.799	67	.920	.391
8	.139	.990	38	.616	.788	68	.927	.375
9	.156	.988	39	.629	.777	69	.934	.358
10	.174	.985	40	.643	.766	70	.940	.342
11	.191	.982	41	.656	.755	71	.946	.326
12	.208	.978	42	.669	.743	72	.951	.309
13	.225	.974	43	.682	.731	73	.956	.292
14	.242	.970	44	.695	.719	74	.961	.276
15	.259	.966	45	.707	.707	75	.966	.259
16	.276	.961	46	.719	.695	76	.970	.242
17	.292	.956	47	.731	.682	77	.974	.225
18	.309	.951	48	.743	.669	78	.978	.208
19	.326	.946	49	.755	.656	79	.982	.191
20	.342	.940	50	.766	.643	80	.985	.174
21	.358	.934	51	.777	.629	81	.988	.156
22	.375	.927	52	.788	.616	82	.990	.139
23	.391	.920	53	.799	.602	83	.993	.122
24	.407	.914	54	.809	.588	84	.995	.105
25	.423	.906	55	.819	.574	85	.996	.087
26	.438	.899	56	.829	.559	86	.998	.070
27	.454	.891	57	.839	.545	87	.999	.052
28	.469	.883	58	.848	.530	88	.9994	.035
29	.485	.875	59	.857	.515	89	.9998	.017
						90	1.0000	.000

Next, unless the two points happen to be at exactly the same elevation, the inclination between them should be measured. To do this, the compass is turned on its side, sighted from point 1 to point 2, and the clinometer bubble adjusted by turning the small lever on the back of the instrument case until the level bubble is centered. The inclination is read on the inside dial of the compass (Fig. 1-3). If other than a Brunton compass is used, a separate clinometer must be acquired.

Next the tape measure is used to determine the distance between the two points. In most places where the two points to be located are reasonably close to one another, the slope distance or actual distance along the ground between them is the most convenient to measure. Although some inaccuracy is bound to result from the procedure, if the tape is stretched directly toward the point to be located and pulled tight enough to eliminate most of the sag, the correct distance within a fraction of a foot should be derived. Where some obstruction lies between the two points, or where there is a gully or depression between the two, it will be necessary to measure the distance in two or more steps (Fig. 1-4).

Finally, the true horizontal and vertical distance between the two points must be calculated. To do this, the reader must refer to a set of trigonometry tables (Table 1-1). To determine the horizontal distance, first look up the cosine of the angle of inclination (usually abbreviated cos). The measured distance multiplied by the cosine of the angle of inclination will give the true horizontal distance. Thus, in the example shown in Figure 1-4, from point 1 to point A we have:

100 ft. × cos 25° = 100 × .906 = 90.6 ft.

From point A to point 2 we have:

100 ft. × cos 30° = 100 × .886 = 88.6 ft.

Total horizontal distance from point 1 to point 2 is:

90.6 ft. + 88.6 ft. = 179.2 ft.

To calculate the vertical distance between the two points, look up the sine (sometimes written sin) of the angle of inclination. The measured distance multiplied by the sine of the angle of inclination will give the true vertical distance. Thus, in the example given in Figure 1-4, from point 1 to point A we have:

100 ft. × sin 25° = 100 × .423 = 42.3 ft.

From point A to point 2 we have:

100 ft. × sin 30 ° = 100 × .500 = 50.0 ft.

And because point A is lower than point 1, whereas point 2 is above point A we must subtract:

50.0 ft. — 42.3 ft. = 7.7 ft.

And as the vertical distance between point A and point 2 is greater than that between point A and point 1, we know that point 2 is higher than point 1 by a vertical distance of 7.7 ft.

To plot these two points on the map to be produced, point 1 is first located at a convenient place on the map sheet. Next a north-south line is drawn through point 1 (by convention, north is always at the top of the page). Then a protractor,

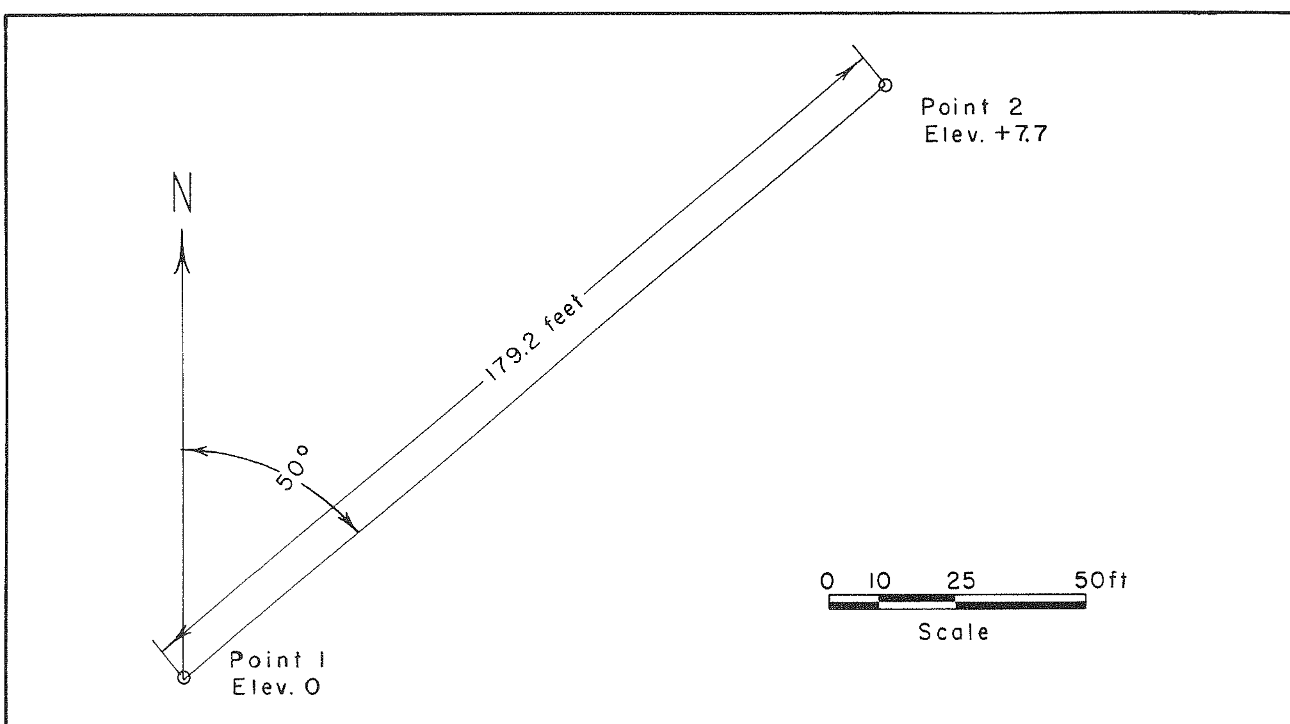

FIGURE 1-5.—Plan showing plotted positions of survey stations.

such as can be purchased at any dime store, is used to mark off the angle between north (or south) and the direction from point 1 to point 2. At the correct angle, a line is drawn on the map from point 1 toward point 2 and the correct horizontal distance marked off on the line (Fig. 1-5). This establishes the relative positions of point 1 and 2. If their elevations are different, this information should also be noted on the map. The scale used is a matter of personal preference. Most mine maps are drawn to a scale of either 1 in. equals 40 ft. or 1 in. equals 50 ft. Small scales for measuring map distances can be purchased at any drafting or school-supply store. The small 6-in. plastic scale with a protractor attached is fully satisfactory.

At this point I should comment upon another aspect of the use of the compass as a hand transit for mine mapping. Having once established the direction and distance between any two points, whether the direction is corrected for magnetic declination or not, the compass should never be used as a compass again but rather as a transit. The reason for this is that although the compass will attempt to point toward magnetic north at all times, it will be deflected by any nearby iron, steel, magnetic ore, electrical installation, etc., including the hand pick or singlejack that you may have stuck in your belt. Mines and mine yards are never free of such items, and thus it can be expected that the compass needle will always be variably deflected one way or the other from its normal direction. Henceforth, then, in establishing the direction to any third or subsequent points on the map, the angle between the two directions must be determined rather than the direction. To do this, using the example of points 1 and 2 to locate some point 3, first sight back from point 2 to point 1, noting the direction indicated by the compass. Then turn the compass and sight toward point 3, being careful not to change your own position relative to the compass any more than necessary. Read the direction recorded by the compass at the new heading and then count or calculate the number of degrees between the two directions. The precaution against changing your own position relative to the compass is primarily because of the hammer that may be in your belt. A change in your position could change the direction and amount of deflection, thus leading to an erroneous reading. Although the hammer may be the worst offender, it is not the only one. A steel-cased wrist watch, or even some steel belt buckles will cause a noticeable deflection of the compass needle.

Mines developed by one or more shafts pose a dual problem in initial layout of workings. We must know not only the location of the shaft collar at surface, but also the location of the bottom of the shaft and that of the different levels beneath the surface. In a vertical or nearly vertical shaft the projection is easily accomplished. One need only drop a plumb line from surface to the bottom of the shaft. In a very deep shaft (an unlikely possibility in a small mine) it may be necessary to work down in several stages. The line can be any strong cord or 20-gauge bare copper wire. The weight at the bottom, ideally, would be a regular surveyor's brass plumb bob, but any weight other than iron or steel can be used. For example, a large lead fishing weight, or even a fair sized rock tied to the end of the cord or wire will serve the purpose.

To establish the direction of a line at the bot-

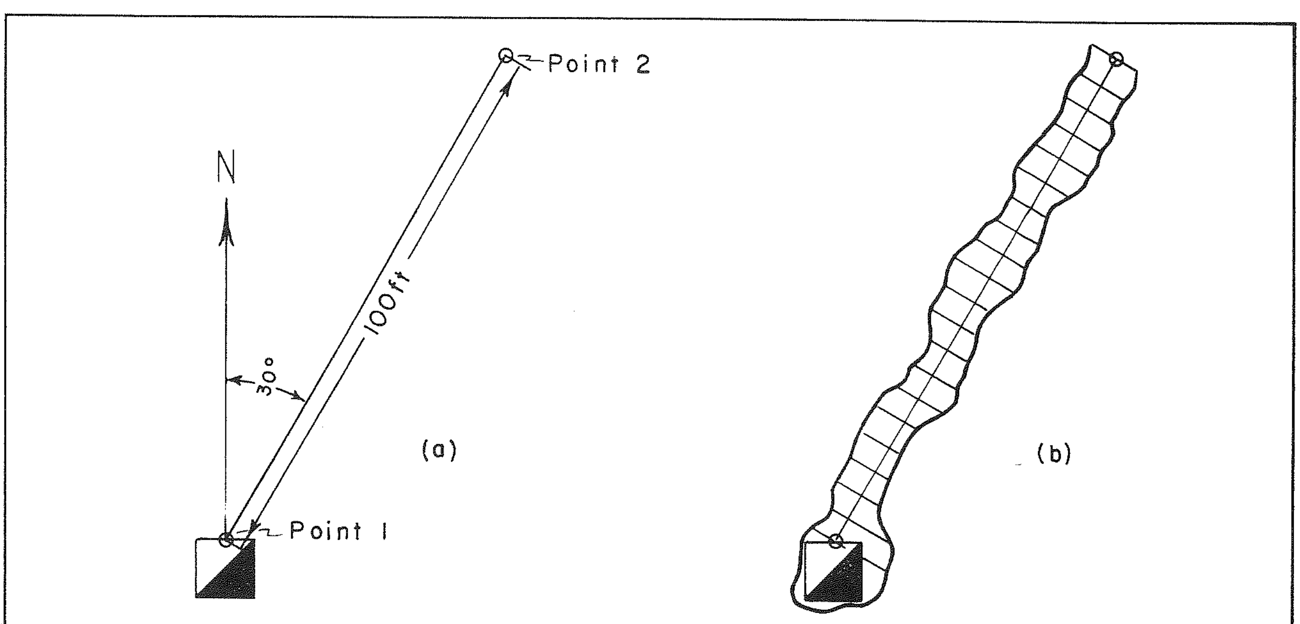

FIGURE 1-6.—Plan showing method of outlining horizontal workings.

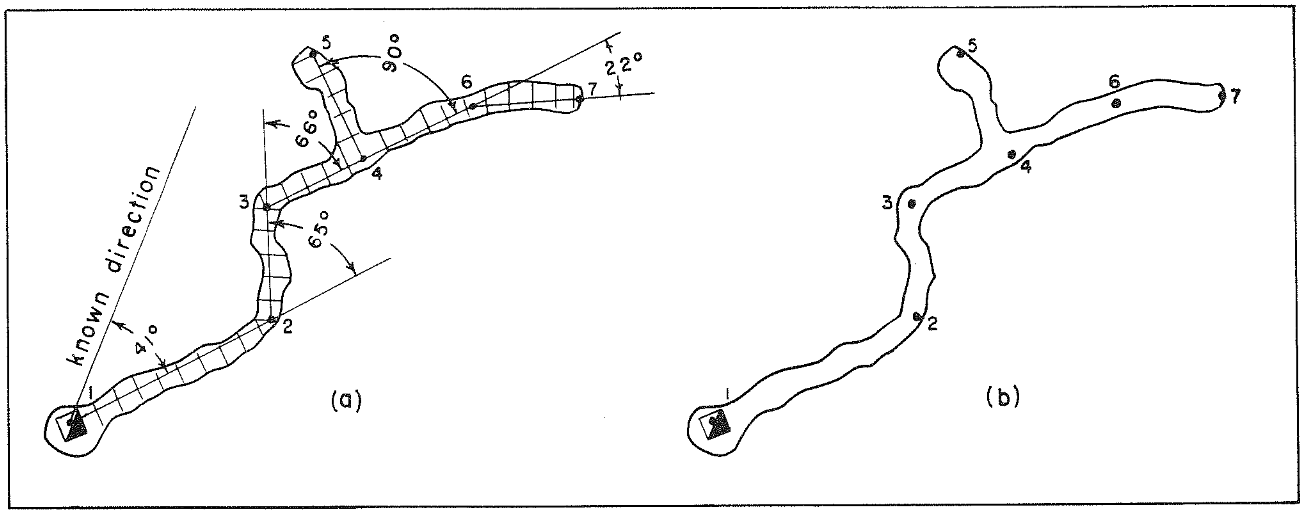

FIGURE 1-7.—Plan of workings on a mine level (a) showing construction lines, (b) construction lines removed.

tom of the shaft, or at some intermediate level, relative to a direction established at the surface, two plumb lines can be used. Place the two lines as close to opposite corners of the shaft as possible, but they must both hang free of obstructions. Then the direction between the two plumb lines at the surface and at any intermediate level will be the same. Although the distance between the two lines, in a narrow shaft, is a short baseline from which to measure, it will serve the purpose if measurements are taken very carefully.

For mines developed by an inclined shaft the method is essentially the same as that in establishing two points at different elevation at surface. Establish the direction, slope distance, and inclination of the shaft as in establishing the distance and direction between points 1 and A (Fig. 1-4). The slope distance can then be converted to true horizontal and vertical components by the method used for surface points. To do this it is convenient to have an assistant carry the end of the tape down the shaft to establish distance, then direct his cap lamp up to provide a visible target on which to sight direction and inclination. Again, for accuracy, be sure to turn the angle between the direction of the incline and a previously determined direction. In a curved or sinuous incline the helper can take any position where his cap lamp is visible at surface or at some established intermediate station in the shaft. In general, you need not be concerned about the curves and jogs in the shaft, but only with the location of level stations. You might, however, feel inclined to direct some uncharitable thoughts toward the person who sank the shaft—unless, of course, that person happens to be you.

LEVEL MAPPING UNDERGROUND

Having accomplished the operations described above, you are now ready to begin the task of mapping the underground workings. Although the preceding may seem somewhat tedious, you can take comfort from the fact that it need be done only once. For that matter, mapping all the workings in an old mine that has never been mapped can be a considerable undertaking, but once the map is brought up to date only the current advance need be mapped each week. In a small mine working one shift per day, the weekly advance may not exceed 50 ft. and can be mapped in an hour or so.

To begin underground mapping, either from a level reached from a shaft or in an adit from surface, stretch the tape out 100 ft. (or as far as possible, keeping the end visible from the starting point or last intermediate point). Mark the point to which the tape has been extended in some permanent manner. A nail driven into a timber cap or into a crack in the rock of the back (roof) with a numbered metal tag (tin can lid is fine) is an ideal means of identification of the point. Then determine the direction of the tape (actually, the angle between its course and a previously determined direction) and draw a line of the proper direction and scale length on your map (Fig. 1-6a). Note the distance to the walls of the opening on each side of the tape at regular intervals and mark them on the map. Connecting these distances with lines will outline the workings along the length of the tape (Fig. 1-6b). In regular openings an interval of 10 ft. will be sufficient. In irregular openings a 5-ft. interval is better. In Figure 1-6b, a 5-ft. interval is illustrated.

From point 2 (Fig. 1-6b) you can then proceed to points 3, 4, 5, etc., until all workings on that particular level are plotted on the map. Remember to 'back sight' or read the direction on a previously determined line (usually the line between the last two major points) and then the direction of the new line. Calculate the angle of change in direction. **Warning: Use the calculated angle be-**

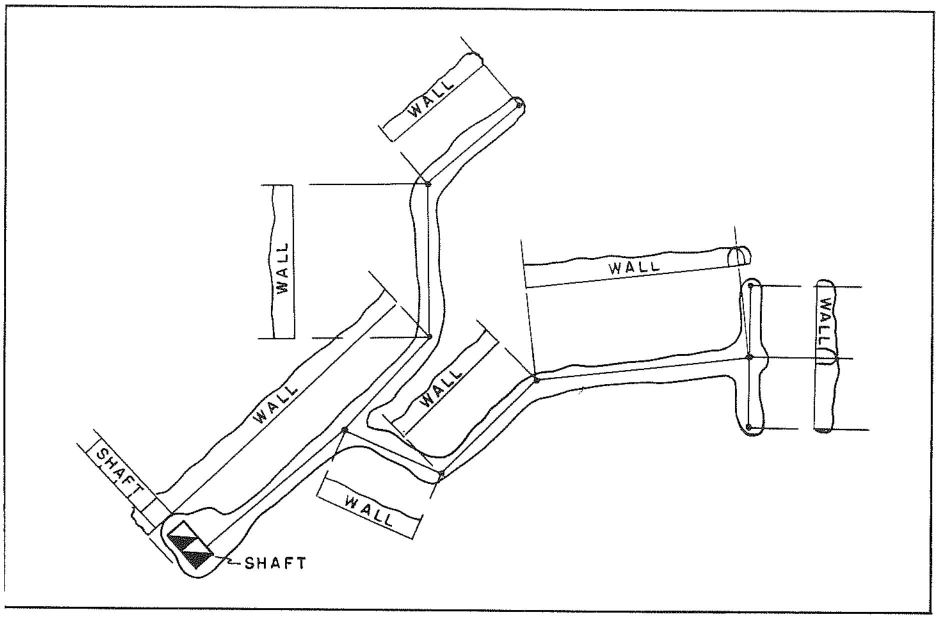

FIGURE 1-8.—Plan of workings showing method of plotting geology along walls of drift or crosscut.

tween the two directions. It is important. A local source of attraction may deflect the compass needle as much as 90° from a true reading, but the angle between two directions from the same point is constant if measured with care. The author has mapped thousands of feet of workings by this method and had an accumulated error, at the end, of little more than a foot.

Figure 1-7a,b shows the workings of one level of a small mine as mapped by the above method. Figure 1-7a has the construction lines used in drawing the level outline; Figure 1-7b shows the map after construction lines and other unnecessary notations have been erased. Figure 1-7a, then, would resemble the working map used underground, and Figure 1-7b, the tracing of the original kept as a permanent record in the mine office.

Note that the map thus far is not a geologic map. It is known as an engineer's plan, which can be used as a base for the geologic map. The next step is to plot the geology of the level on the plan. Where workings are not extensive, it may be practical to outline all of the workings of the level and then plot the geology. In general, however, it is far better to map that portion within one span of the tape measure completely before going on to the next segment.

Before beginning to map geology, give some consideration to the attitude or type of ore body involved, and how it can be shown to best advantage. For ore bodies or veins that are vertical or inclined at a steep angle (a group that includes most small mines) a scale reproduction of the back (or roof) of the workings on the map is most desirable. For some ore bodies that are horizontal, or nearly so, it may be desirable to map one wall of the workings instead (Fig. 1-8).

In either case, set some procedure to be followed. One that has become almost standard among professional geologists is to map the structures first, mineralization second, and lithology (rock type) last. A means of depicting the different features should also be determined in advance. Again, a widely accepted 'standard' exists. That is to show faults (and joints) in blue, ore (and mineralization) in red, and the outlines of workings, contacts between rock types, and all written comments, etc., in black. Other light colors or different symbols can be used to denote different rock types or formations.

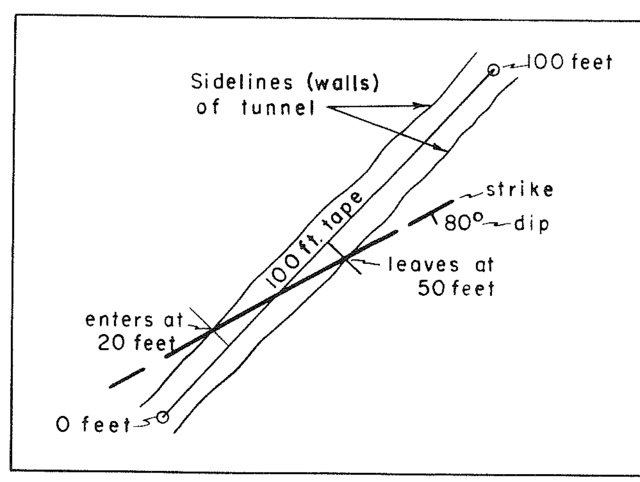

FIGURE 1-9.—Plan showing one method of determining the strike of a structure (fault or bedding plane.)

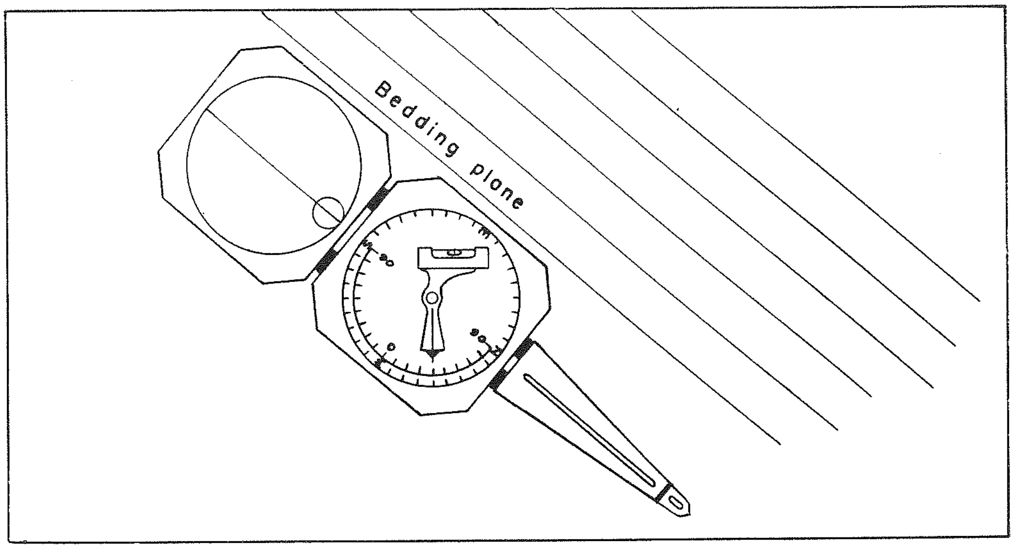

FIGURE 1-10.—Sketch showing use of Brunton compass as a clinometer (showing 40° dip of bed).

Having determined what color conventions are to be used on your map, you can now proceed to the mapping of structures. The most obvious structure in any mine developed in sedimentary rocks is the strike and dip of the sedimentary beds. The strike of a bed, or for that matter of a fault, joint, or vein, is simply a measure of its orientation, and dip is the measure of the inclination. Technically, the strike is the direction of a horizontal line along the surface of the bed (fault, vein, etc.), and the dip is the angle between the bed and a horizontal surface.

To determine the strike of any surface (say a sedimentary bed) and plot it on the map, either the compass or the tape measure may be used. Where the feature (bed) crosses the workings at a shallow angle it is generally easiest to note the distance along the tape where the bed enters on one wall, and the point where it leaves on the other wall; mark these points on the map and draw a line connecting the two points, and that line will parallel the strike (Fig. 1-9). For accuracy, both points should be measured at the same height above the floor, and the outline of the drift or crosscut must be accurately drawn. Either waist or shoulder height may be convenient for the individual. The author, being somewhat taller than most mine tunnels, has found his waist maintains a more nearly constant elevation above the floor than his shoulders, but be your own judge in this matter. The strike having been determined and plotted, the dip can be determined.

Standing at the point where the bed intersects either wall, look toward the similar point where it intersects the other wall. You are now looking along the strike of the bed. Now hold the compass in front of you, turned on its side so that you can see the clinometer bubble, and line up the edge of the compass parallel to the trace of the bed on the far wall. Adjust the level bubble until it is centered, and read the dip on the inner dial of the compass (Fig. 1-10). This information can be indicated on the map by the standard geological symbol (Fig. 1-9), a short 'T' with the crossbar parallel to the strike, the short line parallel to the dip, and the angle of dip written beside it.

If the compass is used to determine the strike as well as the dip of the bed, fault, or vein, you take the same position as when measuring the dip. Stand where the feature intersects one wall and point the compass toward the point where it

TABLE 1-2.—Abbreviations for common minerals and rocks.

Andesite	**And**	**Cuprite**	**cup**	**Monzonite**	**Mz**
Acanthite (argentite)	**ac**	**Dolomite**	**dl-dol**	**Pyrite**	**py**
Arsenopyrite	**ap**	**Enargite**	**en**	**Quartz**	**qt**
Azurite	**az**	**Fluorite**	**fl**	**Quartz Monzonite**	**Qm**
Barite	**ba**	**Galena**	**ga-gn**	**Rhyolite**	**Rhy**
Basalt	**Bas**	**Gangue**	**G**	**Sandstone**	**Ss**
Bornite	**bn**	**Gold**	**Au**	**Shale**	**Sh**
Calcite	**cal-ca**	**Granite**	**Gr**	**Siderite**	**sid**
Chalcocite	**cc**	**Granodiorite**	**Gd**	**Silver**	**Ag**
Chalcopyrite	**cp**	**Hematite**	**he**	**Sphalerite**	**sl**
Copper	**Cu**	**Limonite**	**li-lm**	**Syenite**	**Sy**
Covellite	**cv**	**Magnetite**	**mag**	**Tetrahedrite**	**td**
Conglomerate	**Cg**	**Malachite**	**mal**		

Note: By convention, mineral abbreviations are lower case whereas rocks and chemical elements are capitalized.

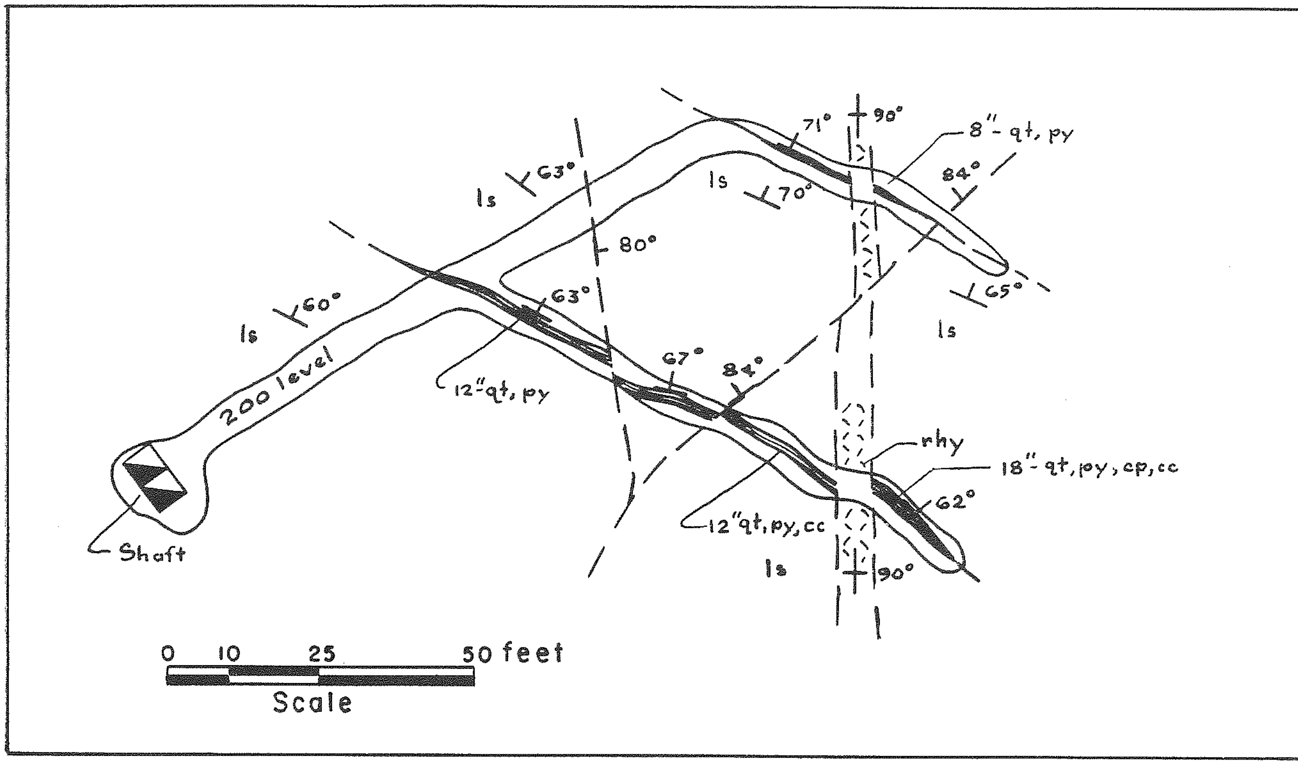

FIGURE 1-11.—Plan showing completed geologic level map.

intersects the other wall. Read the direction indicated on the compass dial, turn parallel to a known direction and read the dial again, and compute the angle. The strike and dip of sedimentary beds encountered in the workings of a mine should be plotted wherever there is a change in their attitude, and for that matter, at least every 100 ft. even where they seem to retain the same attitude.

The same procedure should be followed in plotting all significant faults and joints in the rocks. Faults, by definition, are planes of separation in the rocks along which there has been movement. As such, any fault is worthy of being mapped. Joints are breaks or separations in the rock where there has been no movement (or an immeasurably small one) and, in general, need not be mapped unless affected by mineralization. Special studies of the orientation of joints may be made in an effort to unravel complex structural problems, but this phase of investigation should not be attempted by the amateur.

Faults and veins that have a width of gouge, clay, or mineralized rock of 6 in. or more can be plotted to scale. Narrower features must be shown by a thin line. It is also a good idea to make a brief notation to the side of the feature on the map, giving its size and content (Fig. 1-11). Notations should be abbreviated as much as possible, both for neatness and space conservation. Although there is wide latitude in the abbreviations used, the same notation should be used in any one set of maps. Some commonly used abbreviations for minerals and rock types are given.

In noting the minerals present in a vein or other mineralized area, it is more or less conventional to list them in order of decreasing abundance. Thus, the notation **6" qt, py, cp, Au** would indicate a vein 6 in. wide composed mostly of quartz with pyrite, somewhat less chalcopyrite, and some gold.

In mapping features that parallel, or essentially parallel the tunnel or drift being mapped, they can be viewed on the back (or roof) of the tunnel and drawn in any detail desired on the map.

When mapping, particularly in old workings, the accumulation of muck on the walls and back can be a considerable deterrent to accuracy. The ideal solution to this problem is a water hose with which to wash down the back and walls so that the geology can be readily seen. Unfortunately, such is not always available but a satisfactory substitute can be made from a pump-tank garden sprayer of the type used to spray insecticide or liquid fertilizer on gardens. The sprayer will wash down a considerable area of workings for each filling. In workings in weak ground where lagging has been placed 'skin to skin', there is little hope of mapping more than the outlines of drifts and crosscuts and the location of old stopes, etc. Although far from ideal, even this information can be of considerable help in determining the course and offsets of veins and the location of high-grade areas along the vein. This is particu-

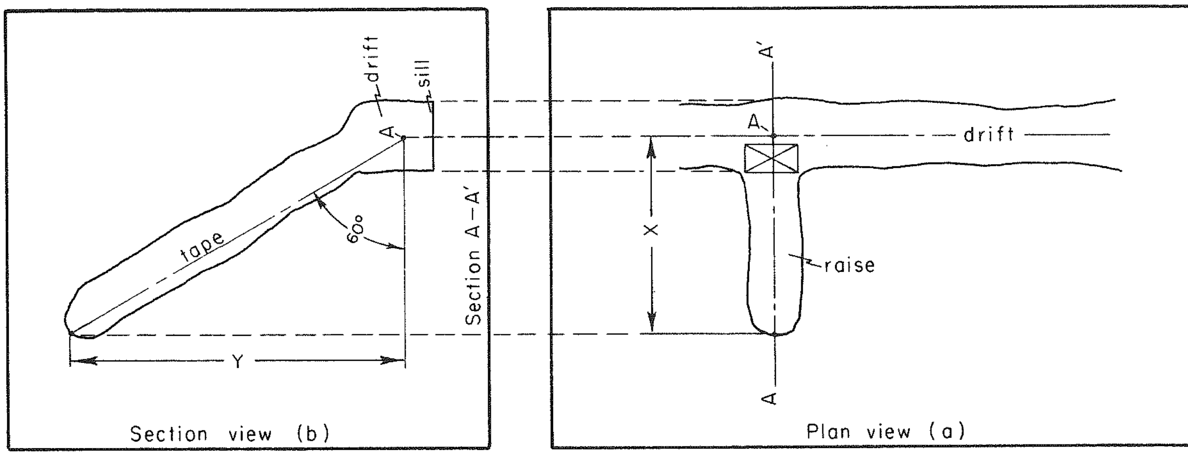

FIGURE 1-12.—Plan and section of a raise. (a) Plan showing the bottom of a raise and its top at a distance 'X', the true horizontal distance to the left of point 'A'. (b) Section view of the raise showing the location of the tape measure, the angle of inclination (60°), and the true vertical distance 'Y' from point 'A'.

larly true of old workings, as the 'old timers' had a propensity for following the ore 'even if it went up a tree' as the saying goes, and their workings will generally indicate accurately the wanderings of the ore.

Figure 1-11 shows the completed map of a small segment of mine workings. Note carefully the different features shown and how they are indicated.

MAPPING IN RAISES, WINZES, AND STOPES

Raises and winzes can be treated as short shafts. In general, the mapping of such features follows a procedure similar to that used in shafts. There are certain differences, however, that affect the attitude of the mapper toward these features. A shaft, if its location has been carefully planned in advance, will avoid ore as much as possible so as not to tie up valuable ore in unrecoverable pillars. Incidentally, the writer has observed that this seemingly obvious rule of correct procedure is frequently ignored by the small-mine operator, presumably because he feels that he cannot afford the luxury of doing development work in waste rock. This is a case of being 'penny wise and pound foolish', and in the final analysis usually proves to be a financial blunder of considerable proportions. Raises and winzes, on the other hand, are more often than not designed to develop ore, and as such, are in or adjacent to ore or rock showing significant mineralization throughout most of their course. Therefore the geology and structure in and adjacent to a raise or winze are significant to the geologist and should be mapped. Unfortunately, steeply inclined or vertical raises (and winzes) cannot be satisfactorily portrayed on a plan map. The only satisfactory means of portrayal is in section view. The mechanics of drawing section views of mine workings are discussed below.

The method of mapping in raises and winzes is little different from that already discussed in regard to levels, albeit somewhat less convenient. The tape measure is stretched up the raise from a point established at its base. Its direction is determined by turning the angle from a previously determined point, and its inclination is measured by use of the clinometer. The correct position of the top and bottom of the raise can then be plotted on the map by calculating the true horizontal and vertical dimensions as was done in Figure 1-4. (See Fig. 1-12a,b for detail on raise map.)

The outline and geology of the raise can then be mapped, using essentially the same procedure as with level mapping. The drawing can be placed off to the side of the main level workings on the working map sheet, or properly placed in section view position (see section on construction of sections), at the mapper's discretion. In an irregular raise, the distance from the tape to the hanging wall and footwall are measured at regular intervals, and the geology plotted (Fig. 1-13) just as in level mapping except that a map of one wall is produced instead of a map of the back.

In a raise that 'holes through' into higher accessible workings, an additional benefit is gained, as the juncture provides a point where the accuracy of the mapping in the two levels can be checked. In general, it will be found that the location of the top of the raise as determined from the map of the level below does not quite agree with the location determined from the level above. If the difference in apparent location is large, then a serious error in mapping procedure is indicated, and the work should be checked carefully to discover and correct the error. If the error is only a foot or so it is usually safe to assume that roughly half of the error occurred on each level map. Thus, the map of each level is corrected (fudged, to be completely honest) so that they agree upon the location of the raise at a point halfway between the two derived locations. The error produced by following this procedure is generally insignificant.

The philosophy of mapping stopes is somewhat different from that involved in mapping raises. In some respects, a stope can be considered as a raise that is extended along the strike of the vein. Mapping the stope, however, may or may not be an extension of the procedure used in a raise, depending somewhat upon the geology of the ore body involved.

Either of two methods of stope mapping may be followed. (A third, actually a construction produced from the maps already made, is described in the section on longitudinal sections.) The first method of stope mapping is to make a series of section maps of the stope at regular intervals along its length, just as was done for a raise. The alternative method is to draw a series of plans, one for each floor of the stope from the sill upward. In a simple vein either procedure will suffice. In complex veins some benefit may be derived from choosing one method in preference to the other. For example, horsetailing or splitting veins that tend to split off to the right (or left) of the main fissure can usually be shown to best advantage on a series of horizontal plans of the stope floors. Conversely, a vein that tends to split in the vertical dimension can best be shown on vertical sections. A condition of this latter type is illustrated in the raise map (Fig. 1-13).

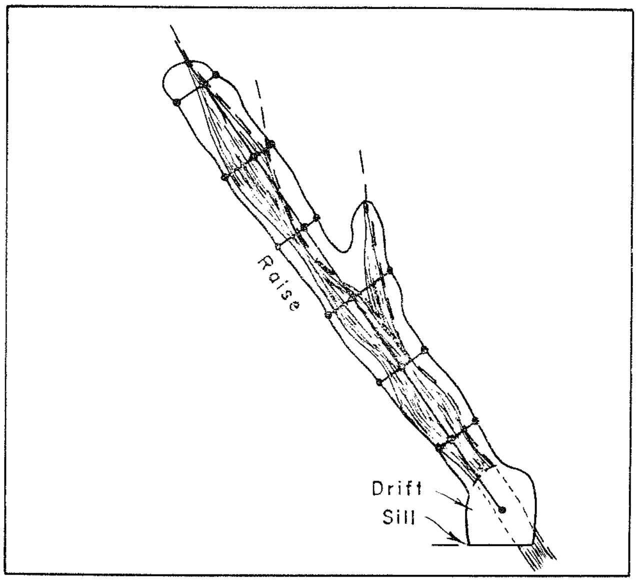

FIGURE 1-13.—Vertical section showing geology in inclined raise.

The procedure for mapping stopes in vertical

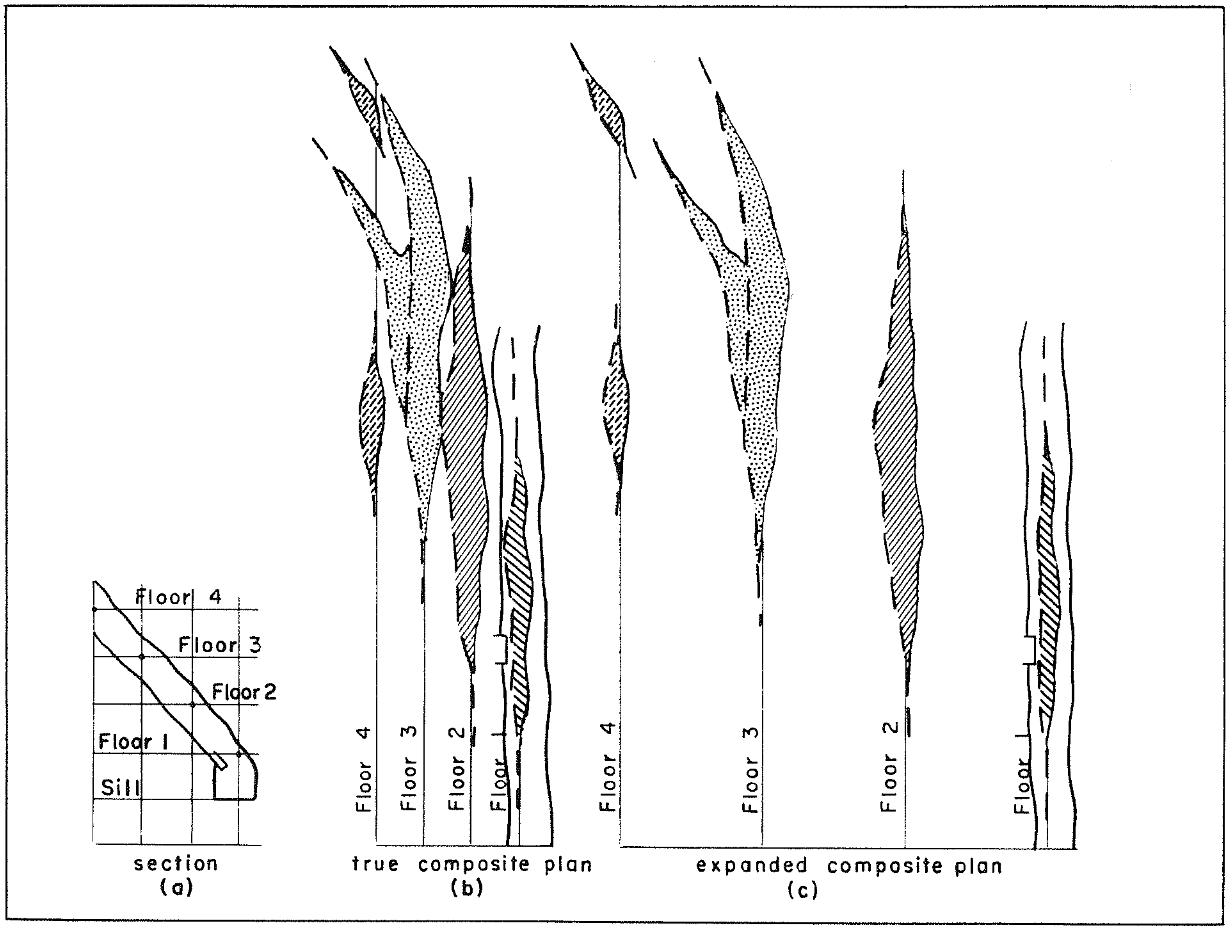

FIGURE 1-14.—Method of offsetting stope floor plans.

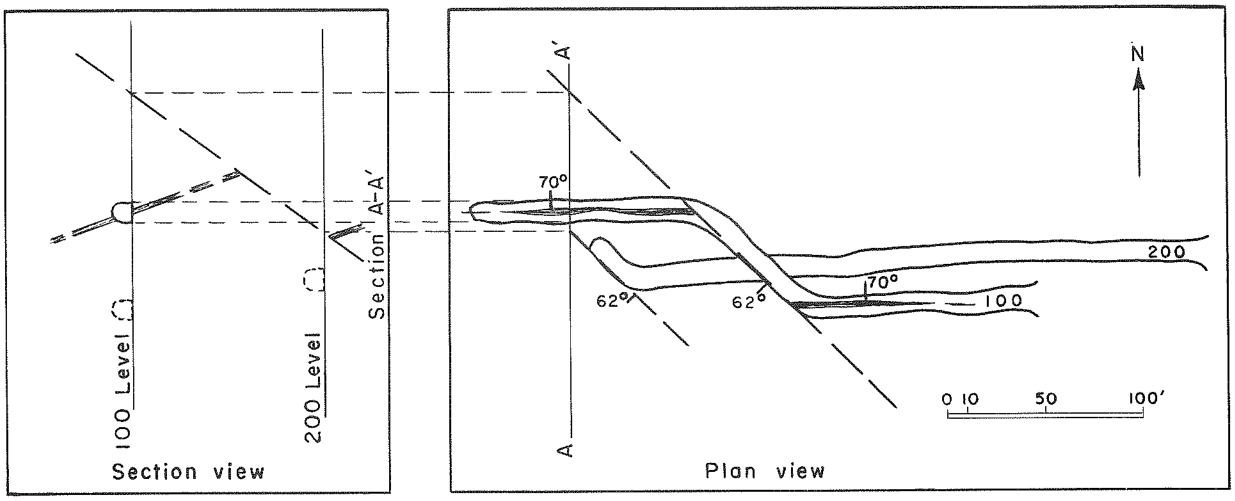

FIGURE 1-15.—Construction of a geologic cross section.

section is identical with that described for the mapping of raises. Sections should be drawn at regular intervals along the length of the stope. The interval chosen is somewhat a matter of choice and may range from 5 ft. in small, complex, high-grade ore bodies to 100 ft. in large, relatively simple ore bodies. Completely satisfactory stope maps can only be made as the stope is developed and mined, while the evidence is still there to be observed. Carefully drawn outline maps of old stopes are frequently of great value, however, and always are worth taking the trouble to map if it can be done safely.

In mapping stopes in a series of floor (or level) plans, the vertical (sometimes slope) interval is usually established by the position of the floors themselves, and is usually 10 ft. First the true position of a point at one end of each floor must be determined. A nail (with numbered tag) in a stull near either end of the stope will serve. Its location is determined by taping to the level below or to the next lower floor of the stope. The individual floors are mapped just as were the drifts and crosscuts of the level below. The geology of the walls is plotted, and that of the back directly above the mapper is projected to waist height (provided, of course, that mapping is done as the stope is mined). In old stopes only the walls and ends can be mapped, together with the gross outline of the stope. One additional complication obtains in the case of vertical and steeply inclined stopes—the floor plans of the stope, when plotted on the map, may completely or partly overlie one another if drawn in their true position. This difficulty can be overcome by distorting the horizontal scale perpendicular to the strike of the vein. In other words, each floor plan is offset toward the footwall by some even multiple of its true offset. This procedure is illustrated in Figure 1-14a, b, c. Note that the map indicates a scale distortion. This is necessary not only for the convenience of others who may have occasion to use your map, but also because your own memory may not be as infallible as you choose to think. The writer has revisited locations (to check on some feature that should have been noted on an earlier visit) enough times to have developed something of a mania for getting all of the infor-

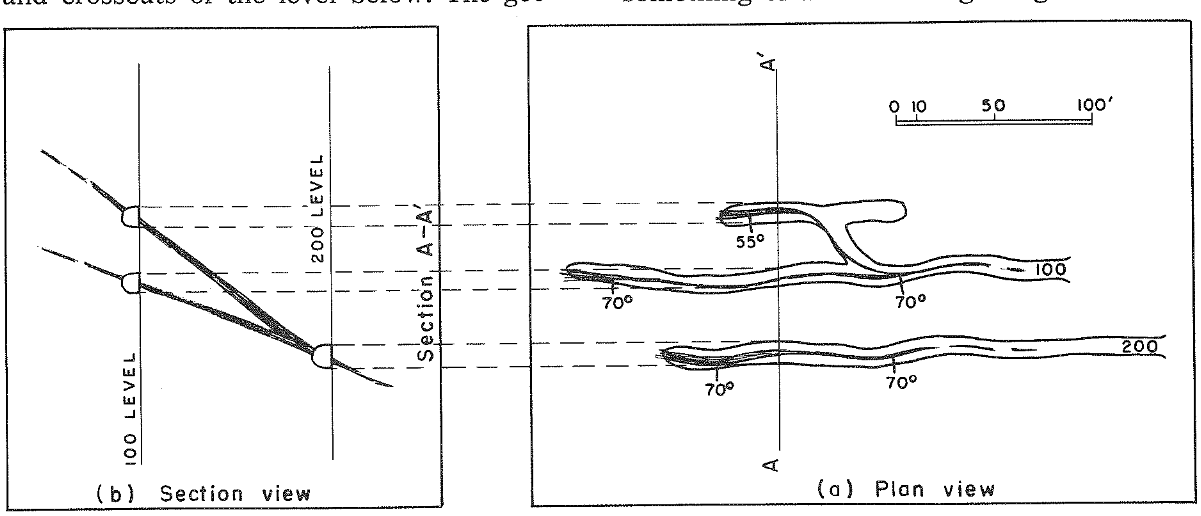

FIGURE 1-16.—Plan and cross section of split vein.

mation on the map at the time of mapping. The return visit can be sufficiently exasperating if the location happens to lie at the top of a mountain. In underground workings the need for original completeness is even more pressing, as the workings may no longer be accessible by the time the need for additional information is recognized.

Mapping of underhand stopes is no different than mapping in stopes located above the sill. Their only additional significance lies in the fact that by their existence they usually provide evidence that 'somebody goofed'. In the 'old days' when miners worked for a dollar a day and 'found' there may have been occasional justification for the infamous underhand. Today, with our ever-increasing production costs, justification is well-nigh impossible.

CONSTRUCTION OF LONGITUDINAL AND CROSS SECTIONS

The drawing of sectional views of mine workings and their geology is a relatively simple process once the fundamentals are understood. The section view is what you would see if you could take a huge knife and cut down through the rocks, separate the two halves, and look at the surface produced by the cut. Two types of sectional views are useful in geological interpretation: (1) the cross section, which is generally drawn on a vertical plane cut at right angles (90°) to the strike of the ore-bearing structure, and (2) the longitudinal section, which parallels or nearly parallels the strike of the ore-bearing structure. For very small mines, the sectional views can be placed directly on the level map sheet without causing too much confusion. For moderate-size to large mines it is best to draw section views on separate sheets.

Figure 1-15 illustrates the construction of a cross section of a small mine developed on two levels. The construction lines that determine the positions of the two levels on the section view are shown as light dashed lines. Note particularly the position of the intersection of the vein and the fault. The fault intersects the plane of the sec-

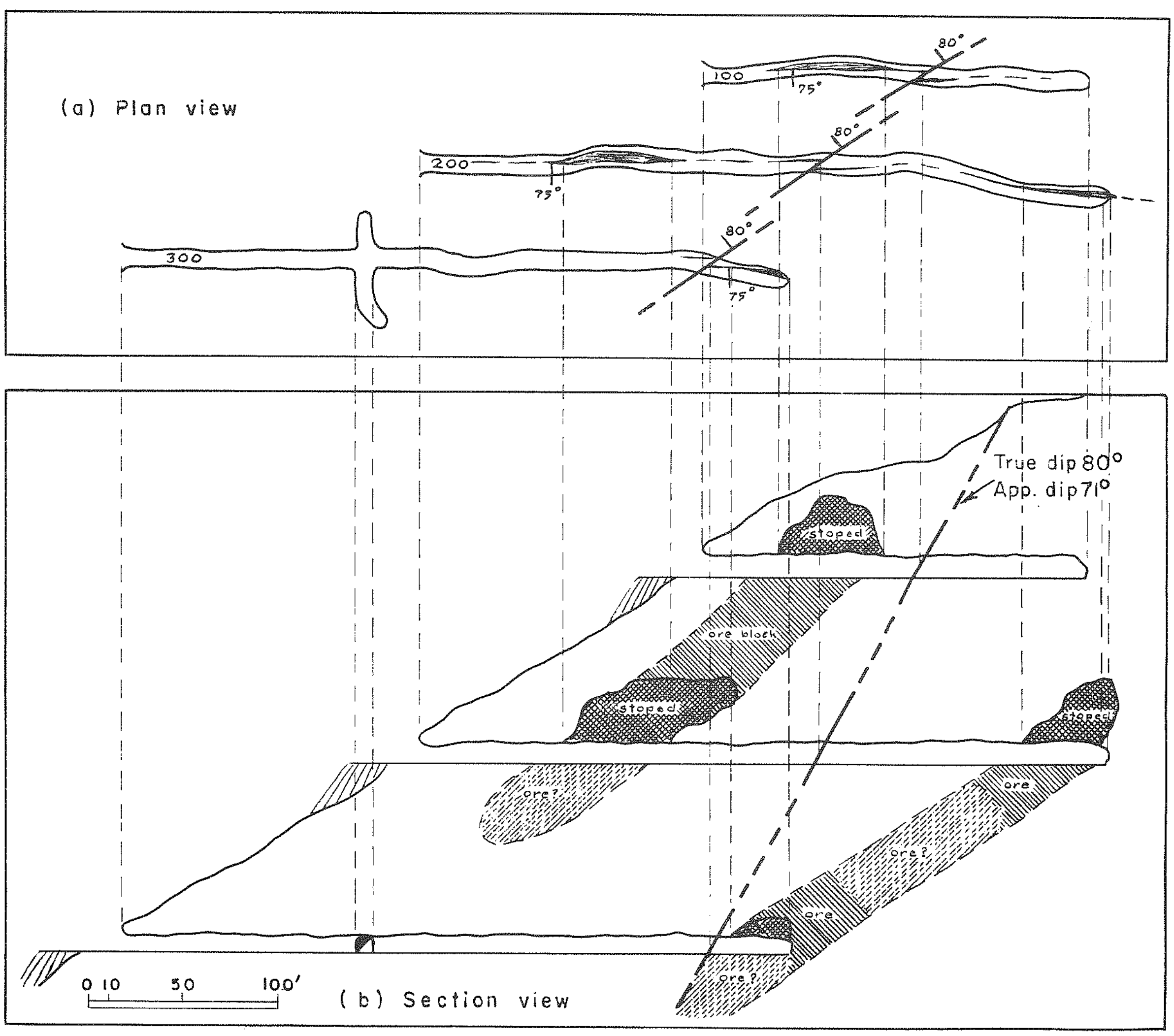

FIGURE 1-17.—Plan and long section of three levels of a mine.

tion north of the upper (100 level) drift, and at an angle to the plane of the section. Because of this angular intersection, the section does not show the true dip of the fault but rather what is called an apparent dip. That is, the angle of intersection of two sloping planes not at right angles to each other is shown. To determine either the true or apparent dip when the other is known, the reader should refer to the chart of apparent dips (Fig. 1-18).

The vein, which intersects the plane of the section at right angles, retains its true dip (70°) in section view. The fault, which intersects the plane of section at an angle of 46°, has a true dip of 62°, but the section view shows an apparent dip of 54°.

Choosing the location for cross section views of a mine requires some consideration of the existing conditions, structures, and information available. As a general rule of thumb, to do a thorough

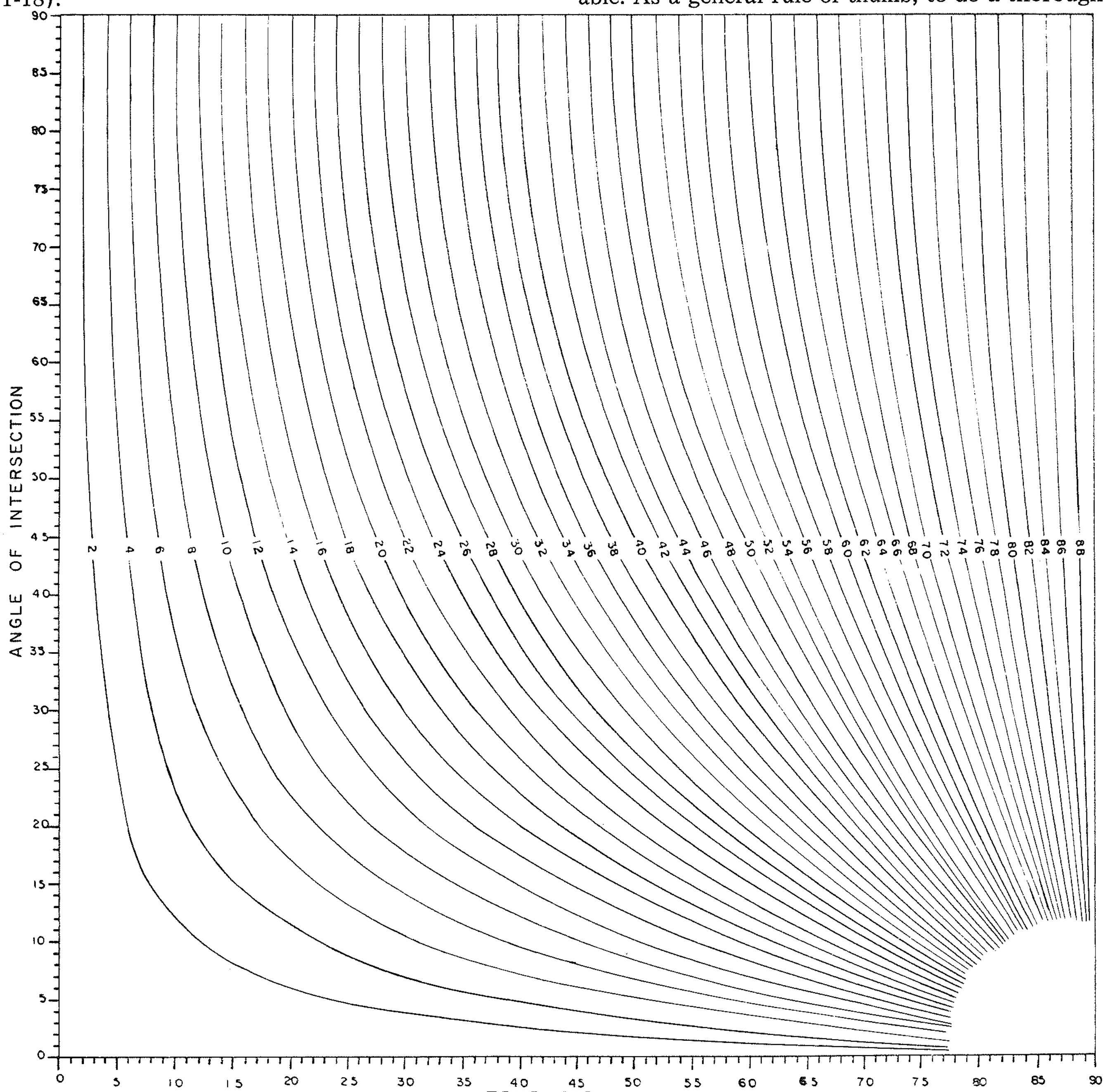

FIGURE 1-18.—Chart for determining apparent dip of structures for cross sections. To use chart, first locate the angle of intersection of the two planes on the scale along the left hand margin of the chart. Follow this line to the right until it meets the vertical line from the correct (true) dip angle. Read the apparent dip on the nearest curved line. If the point of intersection falls roughly halfway between curved lines, the intermediate value is indicated, e.g., a fault that dips 61° intersects the plane of section at an angle of 30°; its dip, in section view, will appear to be 42°.

job a section should be drawn approximately every 100 ft. along the strike of the vein structure. From the engineering standpoint it is desirable to have sections drawn at even intervals throughout the mine, but it is also desirable to draw sections where the greatest possible amount of information is available and where the greatest gain in understanding of the structure will result. A small mine usually lacks the extensive development that will allow the construction of satisfactory sections wherever desired. It is probably best, therefore, to restrict cross section construction to those locations where the available information is sufficient to allow construction of an accurate section regardless of spacing. Note also that the location of the plane of section is clearly marked on the level map so that level and section views can be related to each other easily.

Figure 1-16 illustrates a more complex structural situation in plan and sectional view. Note that although two veins are indicated at the 100 level, they are actually splits of the same vein and no money need be spent in crosscutting on the 200 level in search of a second vein.

Longitudinal sections are sections drawn parallel or nearly parallel to the vein or ore structure, and one longitudinal section should be drawn for each vein in the mine. The long section should be drawn along a straight line regardless of minor variations in strike of the vein. No vein runs perfectly straight for any extended distance, hence a slight distortion will result, but, in general, this is far better than 'bending' the section to parallel the vein perfectly. Where there is a major change in the strike of a vein, it is all right to bend or 'dog-leg' the section, but this writer would recommend that you resist the temptation to do so unless absolutely necessary.

Figure 1-17 shows the plan and long section views of a mine that is developed on three levels. Note that although the plane of the section actually parallels the dip of the vein, the levels are drawn at their true vertical distance from each other. That is, the 200 level is shown 100 ft. below the 100 level rather than the true dip distance between them of 110.3 ft. This is a deliberate distortion that is made to facilitate the estimation of ore tonnages and will be explained fully in the section dealing with ore reserves.

An additional benefit derives from distorting the vertical scale of the long section. Apparent dips of cross structures, such as the fault shown crossing the vein in Figure 1-17, can be determined from the chart of apparent dips (Fig. 1-18). This is easier than following a far more complicated system for determining apparent dips on an inclined sectional plane.

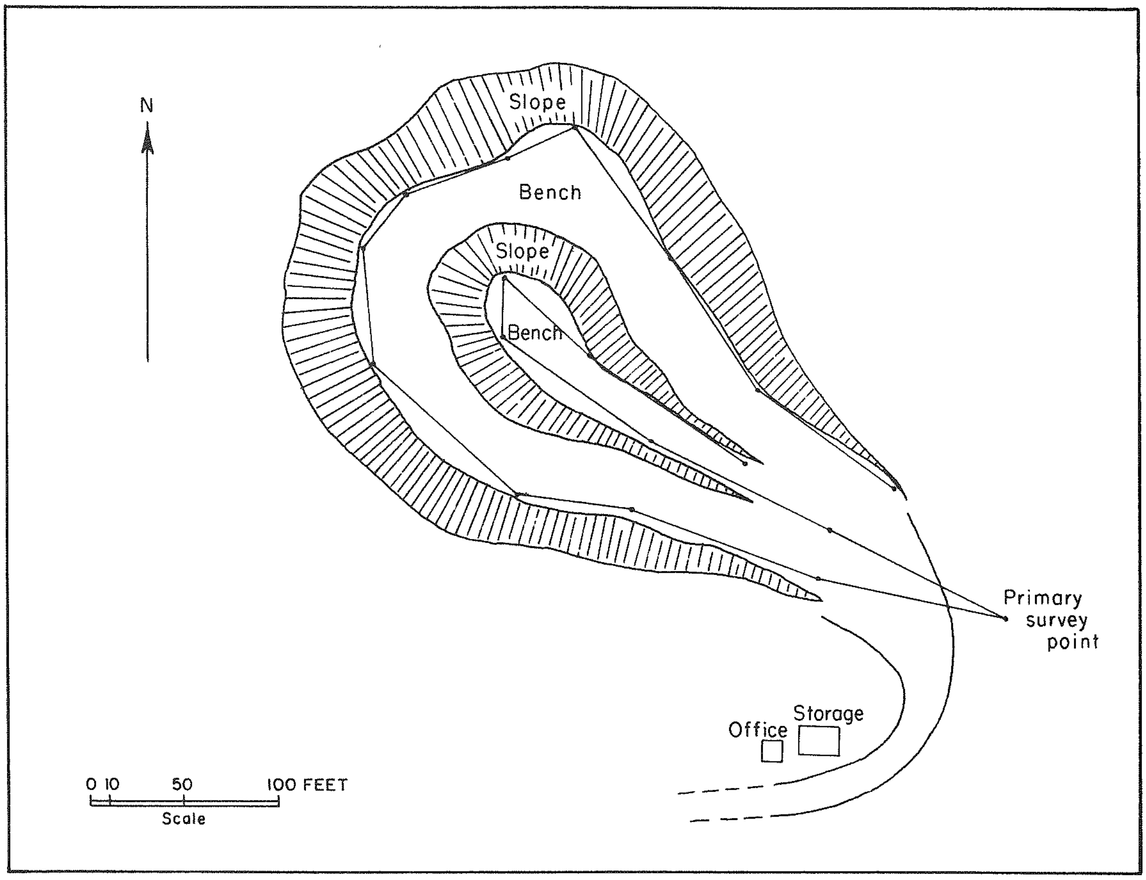

FIGURE 1-19.—Plan map of small pit with two benches, showing survey control and tape locations for mapping.

GEOLOGIC MAPPING FOR OPEN-PIT MINES

The small-mine operator should be cautious about open-pit operations. Only a few metallic ore bodies are amenable to open-pit operations. Certainly there are large economies inherent in the open-pit method, but only if the ore body is amenable to this type of exploitation and only if the operation is carried out properly. The requirements are simple. The deposit must be large enough to pay for the heavy machinery used in mining and still show a profit. That does not mean that it 'looks' large, or that you 'think' it will be large, but that it is known to be large—at least large enough to break even on the initial investment. This usually means a drilling program as a first step in development. It must be wide if steeply dipping, or shallow if more or less horizontal. The term 'strip mining' is commonly applied to mines that exploit a more-or-less horizontal ore body. Many iron, coal, and clay deposits are mined in this way, but few could be considered small mines. From a mapping standpoint, a strip mine can be treated as a pit with only one or a few benches or levels.

In most open-pit operations, the amount of waste that must be removed to recover one ton of ore increases with each foot of depth. If the ore body is narrow, no matter how rich it may be, the pit must be abandoned at shallow depth and the ore mined from underground. It is a common sight to see veins that have been open pitted (actually trenched) to a depth of 30 or 40 ft. and then mining has continued from underground. In most cases, careful study will show that this dual mode of operation has actually cost more in the long run than it would have cost to mine the entire vein 'to the grassroots' from underground.

Because, in theory at least, the location and grade of the ore body should be established through exploration techniques before open-pit mining begins, some might question whether geologic mapping of the mine as it develops is really necessary or desirable. Although it is true that in some limiting cases such maps prove to be of only scientific or historical interest, this does not seem to be the general rule. The reason for this lies in our inability to foresee the innumerable ways in which nature contrives to invalidate our predictions. Modern techniques of ore body evaluation have proved effective in establishing the gross volume and grade of ore but woefully inadequate at predicting the distribution of values within the mass on a scale suitable for day-to-day mining. As a result, most open-pit mines are in a constant state of redesign. Geologic mapping is

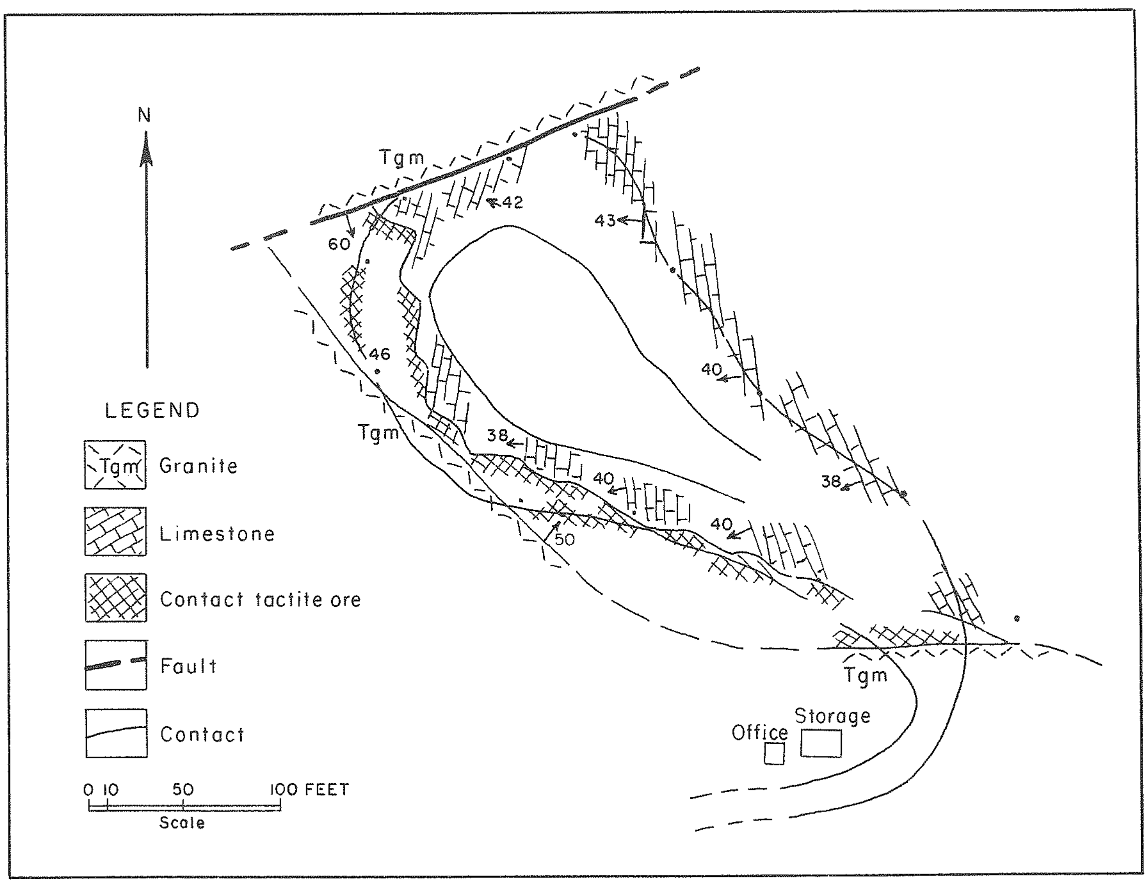

FIGURE 1-20.—Geologic map of upper bench of pit illustrated in Fig. 1-19.

always an aid in predicting the day-to-day scale distribution of ore and waste, and may well be crucial if a major reorientation of pit design becomes necessary.

The mapping of open-pit mines is both simple and complex. The actual geologic mapping is relatively simple, geology being beautifully exposed on the series of slopes of the pit. Unfortunately, the survey control for the map is less simple. In fact, there is no really satisfactory way to map an operating open-pit mine with Brunton compass and tape measure. One consolation lies in the fact that an operating open pit of any reasonable size should be able to afford the luxury of a staff surveyor and helper. If it cannot, there is just cause to question the feasibility of continued operation.

For very small pits, employing possibly two or three men, compass and tape measure traverses will suffice for the survey. In general, it can be assumed that the mining will not proceed so rapidly as to move the benches before their location and geology can be plotted by this somewhat slow and inefficient method.

First a base point must be located, one that will not disappear in the course of subsequent mining operations. An ore-loading bin or dock is a likely spot, or if ore is loaded directly in the pit, possibly the field operations shack will serve. It should be a point with a fair view of the pit, although, if this proves to be impossible, it is always possible to start actual mapping from a secondary point located a known distance and direction from the primary point. Such a secondary point can be temporary and can be changed from time to time as mining operations require.

To start mapping from a primary point, or some more or less temporary secondary point, the engineer selects a bench (or level) that is to be mapped. He stretches the tape along the bench, in a direction determined by the compass. The distance and direction are recorded on the map sheet to scale (Fig. 1-19). The tape should follow along the inner edge of the bench, or where the bench and adjacent slope meet. This is the proper location for mapping.

When you survey, you will find that there is usually an accumulation of talus or debris at the base of the slope. It may be necessary to stretch the tape along the top of this deposit several feet above the bench level. Any error introduced into the map by this fact can usually be ignored. The geology of the bench should be mapped as the survey progresses; first, because the tape measure is already in place in a known location so that features can be plotted without relocating them; and second, because during the original survey the geology is still there to be mapped. By the time the entire pit (even a small one) has been surveyed, some of the rock is likely to have been loaded and shipped away, so map it while you have the chance.

After establishing the location of the tape on your map, sketch in the ground line or face of the slope as accurately as you can. Following this, start to plot geological features. This process is identical to that used underground in a drift or crosscut, except that you will have only one wall to refer to. The other wall may be hundreds of feet away, and direct correlation of features from one side to the other will generally have to be deferred until mapping of the entire bench is completed. Usually, geological features (faults, veins, beds, etc.) are shown extending for a short distance on each side of the ground line. Avoid extending them too far behind the ground line, not only in the interest of accuracy, but because they may interfere with later mapping of a new face. Perhaps obviously, all notes, etc., should be placed on the pit side of the ground line, for otherwise they may have to be relocated later as mining continues (Fig. 1-20).

Pits developed to mine horizontal or nearly horizontal ore bodies (e.g., coal, bedded uranium deposits) require only two or three benches, one in ore and one or two in the overlying waste. The map of this type of pit can be made on a single map sheet, the map of the waste benches being superfluous from the geological viewpoint (not so from the engineering viewpoint). The weekly (or monthly) advance is simply mapped as an extension around the perimeter of the original map. In mapping multi-level pits in ore bodies that have considerable depth, it is better to have one map sheet for each bench or level. The maps are drawn on semi-transparent material (see chapter on map materials) and when they are placed one on top of the other with a strong light below them, the entire pit can be viewed at once. As mining progresses and the benches are mined back, the advance on each bench is plotted on the map sheet for that level.

MAP MATERIALS, CARE, AND STORAGE

Several satisfactory materials are available for map sheets and cross and longitudinal section sheets. The most commonly used material is drafting linen, a fine-woven starch-impregnated cloth. Maps drawn on linen, if properly handled and stored, will last for many years and can be reproduced on different weight papers at nominal cost. Good tracing paper can also be used. It is emphasized that a 100 percent rag paper such as 'Albanene' be used, however. Cheap tracing paper will discolor and become brittle in a relatively short time. A relatively new map material is Mylar film, a clear plastic material that is roughened slightly on one or both sides so that it will take pencil or ink lines. This plastic film has several advantages over other map materials. It is transparent and thus facilitates making copies of the original map when desired; it resists wrinkles, is virtually impossible to tear, and is not affected by spilled water or erasures.

For work sheets, whether for underground or surface mapping, a heavy water-resistant paper is probably best. This material can be purchased at most office supply stores. Mylar film can also be used, taking advantage of its weatherproof surface, but bear in mind that the pencil lines on the map are far less durable than the film. Special pencils may help to overcome this problem, but they don't entirely eliminate it.

Office copies of all maps and sections should be inked. In time a pencil line will become smudged and faded no matter how carefully the map is handled; and this gradual process of attrition of the pencil lines usually manifests itself as a smudge on the next higher sheet in the stack. This is particularly true of colored pencil, but black pencil lines also smudge. As a result, given sufficient time, you not only lose the original pencil line, but the map sheet itself becomes so smudged that it is difficult to make satisfactory tracings or reproductions of the original. Inking should be done carefully with high-quality drawing inks, which are available at all school and art supply stores.

The original work sheets are drawn in pencil. Some care should be exercised in selecting pencils for this purpose. For black pencils 4H or 5H are best; that is, hard enough to retain a sharp point for a reasonable length of time, yet soft enough to make a dark, easily seen line. Colored pencils should definitely not be of the water-soluble variety, for obvious reasons. The harder the better, and fine-line rather than thick, heavy-centered pencils are preferable, as they retain their point better.

Some sort of notebook or clipboard must be used to hold map sheets while you work and to serve as a portable drawing board in the mine. A covered spring-back aluminum clipboard of the size designed to hold 8½ x 11-inch note paper has been found satisfactory. A small piece of wet-or-dry, cloth-backed sandpaper glued to the cover makes an excellent pencil sharpener. Another useful addition is a large piece of blotter attached to the inside surface of the cover. This allows the map sheet to be dried off simply by closing the cover.

Once having gone to the work and expense of providing a good set of maps for a mine, the reader will recognize the importance of proper care and storage of maps. First, of course, they must be kept dry, whether at the operations office at the mine or in an office in town. The storage place should not be too hot, however. This is particularly true if tracing paper is used, as excessive heat will tend to dry the sheets, making them brittle and subject to tears. Secondly, the time-honored practice of rolling maps should be avoided at all cost. Not only does this practice lead to difficulty in keeping the map flat when in use, but the constant flexing as it is rolled and unrolled weakens the material, increases the danger of producing wrinkles and cracks, and over a period of time, tends to cause drawing inks to flake off. A wide-drawer cabinet is the best storage place. A cabinet of several shallow drawers is preferable to one with a few deep ones, as the fewer map sheets that must be gone through to select the map desired, the less wear and tear there will be on individual sheets. A good indexing system is a great help if many map sheets are involved, as the particular drawer where the map is stored can be easily determined.

Finally, size is an important factor. Few small mines will have need for map sheets larger than 24 x 30 inches. If the workings are more extensive than can be accommodated on a sheet of this size, two or more sheets can be used. Large map sheets are always a source of exasperation to the user. They are hard to handle, easy to wrinkle, and the location of interest seems always to be as far from the viewer as possible. It is far better to have portions of the workings on each of several sheets than to have to climb on the table top to find the location that is of interest.

USE OF GEOLOGIC MAPS IN MINE DEVELOPMENT AND OPERATIONS

There would be little point in producing geologic maps and sections of a mine if no benefit were derived from them. Every major mining company in the world retains geologists who are charged with the responsibility of maintaining accurate, detailed, and up-to-date maps of their mines. All this attention to mapping and geology is not simply philanthropic. Large companies sometimes make charitable donations, but not to their own operations.

The uses of geology and the geologic maps and sections of a mine or mining district fall into three categories: (1) in the calculation of ore reserves and production control, (2) in mine layout and planning, and (3) in exploration for additional ore on a local or regional basis.

The calculation of ore reserves is the subject of the following chapter, where it will be taken up in detail. One facet of ore-reserve calculation, however, is more properly considered under the heading of production control and is discussed in the present chapter. Production control is itself a two-phase operation, the first being the maintenance of ore reserves for future production. Obviously, if new ore is not developed as rapidly as previously developed ore is produced, the mine, no matter how encouraging the profits may seem at the moment, is a declining business. Conversely, if new ore is being developed at a rate greatly in excess of current production, the mine is still, technically, in a decline. This derives from the fact that the process of overdevelopment, unless designed to coincide with a planned increase in production rate, causes production and maintenance costs to increase at a constantly accelerated rate. Soon, unless overdevelopment is curtailed, the ore that is being mined is no longer ore in the technical sense of the word. That is, it is not being mined at a profit. The ideal that every mine operator should attempt to achieve is to develop one ton of new ore for every ton of ore mined. Of course it is virtually impossible to achieve this ideal exactly, but every effort should be expended in the attempt. With careful planning, most operators will find that they can come within 10 percent of the ideal, and the rewards for so doing are indeed great. Not only will the operator enjoy the peace of mind that comes with the assurance of continued operation in the immediate foreseeable future, but he will be secure in the knowledge that development expenditures have been kept at a minimum consistent with continued operation.

Maintaining reserves on a 'ton for ton basis' as it is called, is not a particularly complicated process. In a properly run operation it requires that ore blocks already found or indicated by the exploration program be 'moved' from the 'probable' or 'possible' ore category to the 'proven' or 'net mineable' classification as other blocks are mined out. This means driving the necessary level headings, raises, etc., to outline the extent of the block accurately; to allow close estimate of its tonnage and grade; and to prepare it for immediate production when needed. All this should be done at a rate as nearly equal as possible to the rate at which previously prepared blocks are being mined. The methods of calculating the tonnage and grade of blocks are covered in the next chapter; those of developing and mining, in the section on Mining Methods; those of maintaining adequate 'probable' and 'possible' blocks in advance of the development program will be discussed later in this section.

A second phase of production control involves long-range planning to maintain at least reasonably constant ore grade. It is pretty generally known that large companies go to considerable lengths to maintain a constant mill-head grade of ore going to their mill or smelter. It is not so commonly recognized that the small-scale operator might well do the same. There are several reasons for this, the most immediate and obvious one being that a ton of high grade shipped will almost invariable leave behind it one or more tons of low grade that are unmineable once the high grade is gone. When mined and shipped together, not only is the value of the high-grade ore received, but such valuable minerals as are contained in the low-grade ore are recovered as well. As a general rule of thumb, it usually turns out that the best grade to mine is that grade that will just produce a reasonable profit per ton. Of course, this means that production will have to be greater to provide a given profit per month. In the final analysis, however, the mine will operate longer and show a greater earning over its lifetime than it will if stripped of its high-grade ore in the race for quick profits. Then too, one of the most common complaints heard from the small-mine operator is that he is getting a rough deal from the smelter; that he is not getting paid for all 'values' contained; that treatment charges are too high; and that penalties are too severe and credits too small. The first of these objections usually reflects poor sampling on the part of the operator (see chapter on Calculating Reserves). The ore shipped is not as rich as he thinks. For the other, the writer can only suggest that the operator try providing the smelter with a regular flow of ore of relatively constant grade. It is just possible that he will find that his business is welcomed somewhat more enthusiastically. Remember, you are now a salesman and it is up to you to make your product attractive to the customer.

The matter of using geology in mine layout and planning is properly a phase of mining engineering and is covered in a later section of the manual. Basically, the problem is to lay out the mine as simply as possible, as conveniently as possible, and at the lowest possible cost both initially and subsequently. The first two factors require a knowledge of the ore and its occurrence; the structural factors that control ore locations and grade; the geometry of the deposit—that is, the known or probable positions of ore bodies, lenses, or shoots. The third, that of initial and subsequent cost, demands a knowledge of the geology and structure not only of the ore but of surrounding areas.

We have all heard the statement that a straight line is the shortest distance between two points. In mining, although the statement is still technically true, the straight line may not be the 'best' distance between two points. Granted that a short, straight crosscut, or a shaft collared directly above the ore may be the shortest route to the ore, it is very likely to be an expensive mistake. Shafts and haulageways are semi-permanent openings in the mining operation and it is often far better to go the long way around in hard, firm ground than a short distance through faults, brecciated rock, or heavy ground. Even though the distance is greater and the initial cost of drilling and blasting may be greater, far better this than to require constant repairs and retimbering over a period of years, or worse yet to lose the heading or shaft entirely because of caving. The mining engineer uses every scrap of geological information he can find (from your maps and sections) to lay out the workings so as

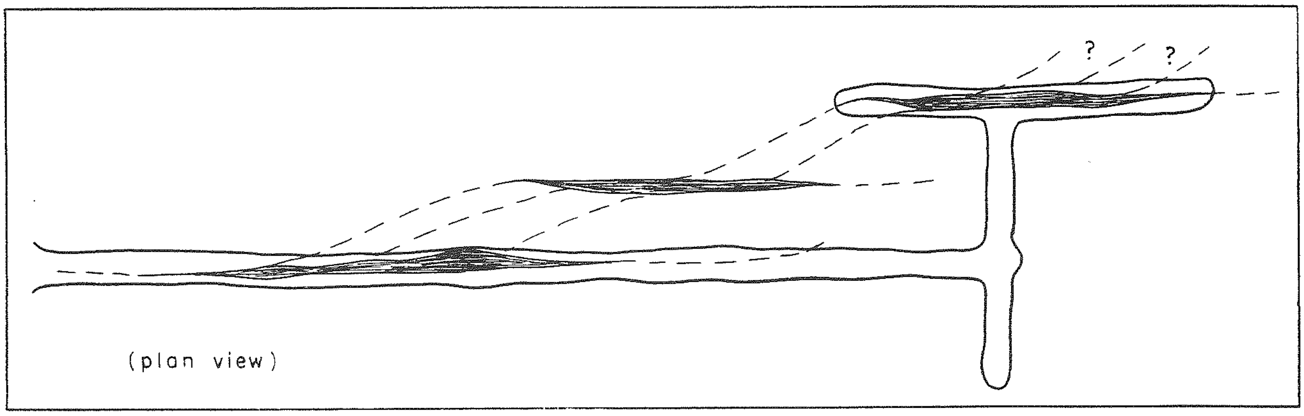

FIGURE 1-21.—En echelon veins. Note that although blind crosscutting has located the third ore shoot, the second in the series was missed.

to avoid major structures and bad ground, and if this should prove impossible he will make every effort to cross such structures at right angles so as to minimize the footage that can be expected to be troublesome in the future. He will also take a close look at the geologic map in an effort to foresee heavy influx of water and other potentially dangerous situations. For example, in mines that have had an earlier period of operations, adequate maps of old workings may prevent a seriout accident such as might result from unexpected breakthrough into an old water- or gob-filled stope. Contacts, especially those between igneous and sedimentary rocks, and faults and fault zones frequently serve as channels for ground water. Faults with heavy clay on one or both walls may hold back water under tremendous pressure head until they are breached by an advancing tunnel, raise, or other opening. If such a condition is anticipated, long steel can be used to test the ground well in advance of current work, thus possibly preventing a fatal accident. Even without the consideration of accident, it is well to anticipate such major problems so that the necessary pumping or drainage facilities will be ready, or for that matter, to allow time to weigh the cost anticipated against the amount of ore likely to be developed and make a sound decision as to whether the heading should be continued or not.

Finally, there is the matter of exploration for new ore, and here geology comes into its own. On a gross scale, geology determines what the ore structure is, whether fault fissure, sedimentary bed, igneous contact, or what have you, and where it is located. In general, it does not take much of a geologist to determine these facts. Veins or ore bodies that are ore from top to bottom and from end to end are rare, however, and for all practical purposes they can be regarded as nonexistent. The trick, then, is to find out where the ore shoot is in the ore structure, and more important, why it is there, so that other ore shoots can be sought intelligently. If there is more than one ore-bearing structure, where are the others, how many are there, and what relationship do they have to one another? If the ore is displaced (faulted), where is the displaced portion? If only the structure is displaced, where is the extension, and is there likely to be ore in it when and if it is found? Finally, what will the ore be like 100, 500, or 1,000 ft. farther down? Will there be ore at all, will it be high or low grade, will it be of the same or a different metal? All of these questions are asked of the geologist, although the answers are not always forthcoming from available information. Certainly, the more information that is available, the greater the chance of a satisfactory answer.

The first step in utilizing geology in planning exploration is careful study of the vein structure in present and past workings. This calls for careful mapping of the structure and study of the resulting plans and sections. Look particularly for parallel vein segments and false footwalls and hanging walls. Often the existence of both footwall and hanging-wall veins is known, but though one is rich the other may be lean. It is well to check the lean vein from place to place anyway. As the ore pinches down in one vein it may be improving in the other. The stories are legion of footwall or hanging-wall veins that parallel the known vein only a few feet away, but were found at a later date after the mine had passed from the hands of the original owners. Not all of these stories are legends. The writer has had occasion to see several such situations. Careful study of vein geology will frequently point out the existence or possibility of such parallel features. Some veins are knife sharp and simple, but most are complex on a detail scale, a maze of pinches, swells, splits, and breaks. Vein splits are of especial interest, for although they may just tail out to nothing, they may, conversely, be feeders in an en echelon system (Fig. 1-21). It is impossible to estimate how many such structures have been missed in small mines, but the number that have been found in mines employing careful mapping as an aid to exploration suggests that there have been many. Even with careful mapping it is a good rule to drill fairly long holes into the walls at

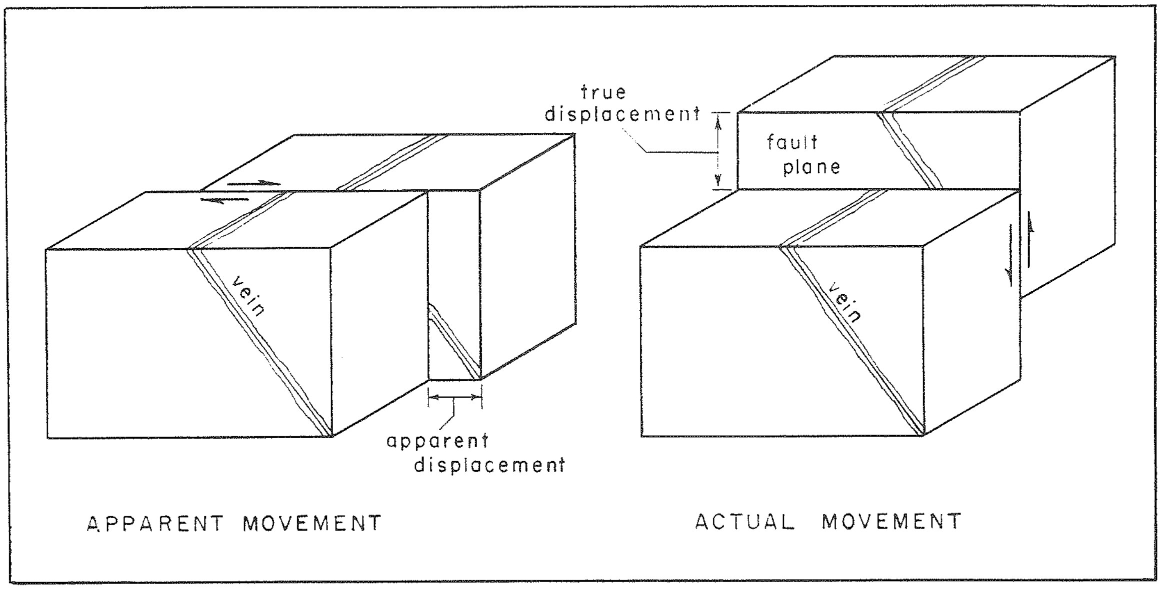

FIGURE 1-22.—Block diagrams of fault displacement, vertical movement.

regular intervals along the vein as a standard procedure. The cost is small and the possible return can be tremendous.

Next, all known ore shoots should be carefully studied. It has been said that any ore body is a miracle of considerable magnitude. By and large, the elements are more or less evenly distributed throughout the earth's crust. That they should be concentrated at all, locally, is a phenomenon that bears careful thought. Most mines are developed on ore structures that are measurable in terms of miles, yet the ore is usually more conveniently measured in terms of feet, or at most hundreds of feet. It hardly seems necessary to state that there must be a reason why the ore is located precisely where it is. To state this obvious fact is easy, but to discover the cause of localization is far more difficult. As a matter of fact, innumerable ore bodies have defied logical explanation for generations, yet it is still well worth the effort to try to uncover their secret. A few common ore localizers are worth looking for: (1) cross fractures, which may be major structures in their own right or so small that they are detected only by the most meticulous examination, yet study may prove that ore occurs only at points along the vein where they occur; (2) flattening or steepening of the dip, again the variation may be such that it is easily recognized or so slight that it is detected only after careful construction of maps and sections, or careful measurement in stopes; (3) variations in strike, which, like variations in dip, may be of any magnitude; (4) change in wall-rock lithology. Hardly anyone would fail to recognize the change as a vein passed from igneous to sedimentary rocks, but the change need not be so obvious. An apparently monotonous expanse of limestone may be slightly more dolomitic locally; there may be a change in type or degree of cementation of sedimentary grains, or there may be a minor change in mineralogy of rocks adjacent to the vein. Note that although it would be nice (and it is the geologist's constant endeavor) to understand why some such feature has localized ore, it is not always necessary to know the why to make use of the observation. For example, if it is observed that ore shoots are restricted to points where the vein flattens slightly, a search for new places where this is likely to occur (use of cross sections) may be rewarding even though the reason for ore accumulation in these flats may be (and usually is) a subject for heated debate.

Where two or more shoots have been developed or mined out in a mine (and this applies particularly to mines with extensive old workings) the location, size, and shape of old ore shoots can conveniently be plotted on longitudinal sections and their shape, plunge, and relation to each other can be studied. In an ideal case it might be noticed that individual shoots lie en echelon in position (that is, adjacent and either higher or lower than the last one). Such an arrangement provides a better-than-average target for future exploration. Even without this ideal space relationship, study of size, shape, and plunge may provide valuable information on the direction and extension that new ore will have when it is found, thus facilitating development and estimation of reserves. In some cases, there will be no immediately apparent relationship between the several shoots, but careful study may uncover an unexpected relationship. Some examples follow: (1) study of vein thickness may disclose that most high-grade shoots lie directly below noticeable pinches in the vein structure; (2) study of mineralogy may show that some mineral (possibly a minor accessory that has no value of its own)

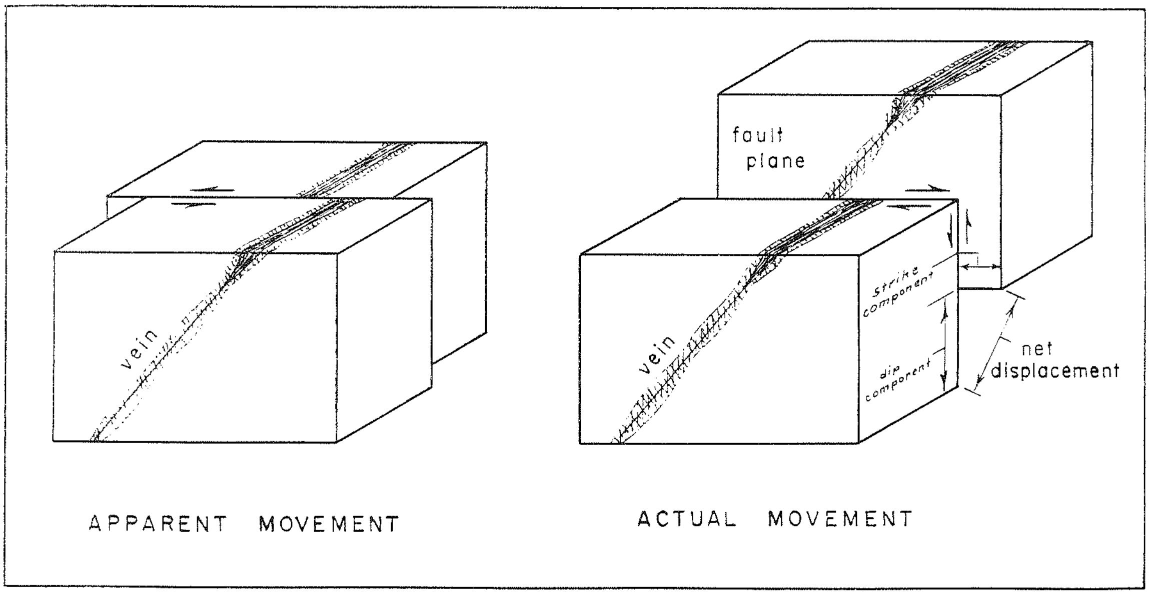

FIGURE 1-23.—Block diagrams of fault displacement, oblique inclined movement.

either appears or disappears as you approach ore; (3) study of stope assays may show that an increase or decrease in some minor element is a harbinger of ore; (4) in some places careful mapping and study has shown that where two or more shoots were thought to exist, actually the ore occurs as a rich 'halo' surrounding a large horse of waste. The knowledge that ore is restricted to the margins of waste blocks of a certain character can completely alter the philosophy of exploration and development.

Faults provide many of the knottiest problems that face the geologist. Mines that are unaffected by fault dislocation are virtually unknown, and some districts have become world famous for the complexity of faulting that has been encountered. The first step in the solution of a faulted vein or ore body is careful scrutiny of the level maps and sections. If they have been drawn carefully and in detail they may offer a clue to the direction of movement. Even though a large fault offers little in the way of clues, small offsets on minor parallel faults nearby may show that all faults of a given set have had similar movement. It is then a good bet that the large fault, if parallel to the smaller faults, will have moved in the same direction. It should be noted that just because the exposed vein is offset in one direction by a fault it does not necessarily follow that the fault movement has been horizontal and in the indicated direction. Vertical movement, when on a fault that cuts an inclined vein, can cause a displacement that appears to be horizontal on casual examination (Fig. 1-22). If the problem is only to crosscut to get back on the vein structure this subtle difference in manner of displacement is purely academic, but if the problem is to locate the displaced segment of an ore shoot, it may be critical to determine exactly what the true displacement has been. We speak of a fault that has been displaced horizontally or directly along the strike of the fault as a strike-slip fault (may also be called a right or left lateral fault, depending upon whether the block on the far side of the fault plane has moved to the right or left of the observer). A fault that has moved vertically, or directly up or down the dip can be called a dip-slip fault (or alternatively, a normal or reverse fault depending upon whether the hanging wall has moved down or up relative to the footwall). In nature few faults are either entirely strike-slip or dip-slip, but rather the true displacement (net slip) has both strike-slip and dip-slip components. Combinations of strike- and dip-slip movement can create interesting problems in fault solution (Fig. 1-23). Note that although the vein is thrown 40 ft. to the left, the ore shoot has actually moved 40 ft. to the right and 100 ft. upward. The difference from an operational standpoint is too clear to require comment.

Careful examination of plans and sections may disclose no solution to the fault problem. The next step, in an old or established mining district, is to check on known displacements at nearby mines. Most parallel or near-parallel faults within the district will have had similar movement. Again a word of caution is in order. Although the above rule of thumb will work in most cases, there are just enough exceptions to the rule to make any new fault an interesting phenomenon. Perhaps the best rule in dealing with any fault is to avoid overconfidence.

Finally, if the fault still resists solution, there is another simple procedure that has produced excellent results (McKinstry, 1948, p. 348). This method involves plotting all known information concerning the two sides of the fault on separate sheets of tracing paper. One sheet would have all workings, veins, faults, contacts, rock types, etc., known to exist on the hanging-wall side, and the other would be similarly constructed for the footwall side. Obviously, the more information that is available the better the chance of success. The two sheets are then superposed in their present relative position and then moved until like features on both sides of the fault plane match as closely as possible. The amount and direction of movement needed to provide correlation can then be determined.

If the fault problem resists all three methods of solution, it is safe to assume that this fault is not for you, and professional help is indicated.

The question of whether cross-faulting is post-mineralization or pre-mineralization is frequently raised. That is, did fault movement occur after the ore was emplaced or before? Although this problem is frequently studied and argued at great length, from a practical standpoint the only difference is that if the fault is post-mineralization, you will search for the displaced segment right now; if pre-mineralization, you may wait until next month. The philosophy is this: if ore is cut off by a post-mineralization fault, you will find the ore when you find the displaced portion (unless, of course, it has been moved up above the present earth surface or so far down as to be unmineable). If the ore is cut by a pre-mineralization fault, the ore-bearing structure will be found in the displaced segment but it may or may not contain ore. Although there is less certainty of finding ore in the displaced segment, the structure cut off by the cross fault carried ore, and any prudent operator is going to want to locate and test the extension sooner or later, although such exploration may not be given first priority.

Changes in ore mineralogy upon passing from the oxide to the sulfide zone, and with increase in depth or extension along the strike within either zone, is an ever-present ogre that stands between the operator and complete peace of mind. Such prediction is always a tough problem, even under the best of conditions, and in general, calls for the services of a specialist. Even professionals display a perversity for sprinkling their opinions with 'ifs', 'ands', and 'buts'. This moral weakness is not surprising when you stop to consider that the literature on the subject, when layed end to end, would stretch very nearly from here to eternity, yet all of it can be summarized by the statement that we still do not know what causes many of the mineralogical changes that occur in ore deposits.

The much-dreaded change when the oxide ores are depleted and the mine must begin to mine sulfide ores is by far the most predictable. The clues are usually to be found through careful examination of the oxide ore. Bits of relict sulfide within the oxide grains will indicate what the original mineral was, or if none such remain, relict or 'ghost' structures or textures may offer sufficient clues. Such study usually requires the use of a microscope and perhaps chemical tests as well, and will generally call for professional services. Within zones, particularly within the sulfide zone, there are general rules of thumb that apply to many districts and which find corroboration through laboratory studies. Here, it would be better to seek professional help if the problem is pressing. In some districts, one or more mines may be developed sufficiently in advance of the others that they may provide evidence of what is to come for their neighbors. It is not safe to assume that one mine will have the same changes in mineralogy as its neighbor, but it is generally true that similar changes will take place and at roughly the same depth.

Finally, 'geologizing' a mine calls for a good deal of philosophy or 'dreaming'. After all, the geologists' eyes cannot penetrate solid rock any better than anyone elses. The trick is to prevent those 'dreams' from getting out of hand. The professional geologist, in spite of his dreaming, is usually a chronic pessimist (because he is aware of the problems and pitfalls, the hard facts of his science). The owner-operator of a mine, conversely, is almost always an indefatigable optimist (because he must be if he is to retain his sanity). The two together make an almost unbeatable combination if only they can learn to live with each other. The operator-geologist or geologist-operator is a nearly ideal one-man team for the small mine. It is the writer's hope that the preceding discussion will help to produce more of this rare breed of man.

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CHAPTER 2 — ORE RESERVES

By

F. N. EARLL

INTRODUCTION

There are few steps in the mining operation where more benefit can be gained at nominal cost in time and money than in the maintenance of good records of ore-reserve tonnages and grades. Despite this, there is probably no area of mine operation that is more consistently ignored by the small-mine operator. There are several apparent reasons for this. First of all, of course, many small-mine operators tend to view their business on a day-to-day basis, a viewpoint that is responsible for more than a few small-mine closures. Secondly, the process of reserve estimate is inherently inexact, and the philosophy of some operators seems to be that if the estimate is not perfect, why bother with it at all. Finally, there are those who for one reason or another seem to prefer to remain ignorant of the horrible truth. These last can be subdivided into those who have a nefarious reason for wishing to avoid the subject, and those who cling to the old adage that in ignorance there is bliss.

Any mine operator who has shipped ore at one time or another and received a bill for its transport in place of the anticipated check for its value has had adequate demonstration of the value of proper reserve estimates. If you are one who has experienced this catastrophe you need not feel embarrassed, as the list of your fellows who have received a similar shock is a long one indeed. The lesson may not be quite as drastic as this, however. Even if your return is occasionally (or always) 10 to 25 percent below the anticipated amount there is good reason to suspect that something is wrong somewhere along the line. Of course, this can be (and usually is) blamed on the smelter; but in the first place, this does not do a thing for your bank balance; and in the second place, it usually is not true.

Another case in point involves the operator who spends a good part of his capital, or possibly goes into debt, to purchase new equipment or develop a new level or area in his mine only to find that the anticipated ore is not ore (noncommercial) or is insufficient in quantity to repay the investment.

The point of all this discussion is this: it is all very simple to set down the rules and methods of estimating ore-reserve tonnages and grades, but it is a waste of time unless operators use the information. The philosophy can be stated simply. You cannot set out to operate a business with any reasonable assurance of success unless you have sufficient information to allow in advance a close estimate of revenue as well as capital investment. You can not hope to know how much you can and should invest in plant and equipment unless you have a reasonably accurate knowledge of the quantity of ore that is available (at least the minimum quantity). Moreover, how can you hope to sell your product at a profit without knowing what it is worth?

The following discussion is presented in several sections. Sampling is given precedence because proper sampling procedure is the heart of all ore-reserve calculation. Sampling is both an art and a science, and all the fancy mathematics in the world will not provide a reliable reserve estimate if the samples are not dependable. The other sections deal with the spacing of samples and the calculation of reserves for different types of ore bodies, as no one system will serve for all deposits.

SAMPLING

First of all, it might be wise to define the term sample as it is used in mining. There is, or there should be, a careful distinction made between the terms sample and specimen. A specimen is a piece of mineral or ore, or for that matter, waste or anything else that is of interest. It can be put in your pocket, or in a box or a drawer, it can be placed on a shelf, in a glass display case, or in a bank vault. The one place it should never be put is in a sample sack that is to be sent to the assayer, for no matter what the assay shows it has been a waste of money. A sample, on the other hand, is a part of something (in this case an ore body), which is representative of the whole. In practice, the sample is intended to be representative of a predetermined portion of the whole, and the aggregate of a group of samples, properly weighted, representative of the whole.

Different types of samples can be used under different circumstances. The so-called chip sample is simply a series of small pieces or 'chips' knocked either systematically or at random from a face or ledge of rock. The chip sample is a lazy man's sample and for small mines should never be used. Unfortunately, much of the poor sampling that is practiced at small mines results more or less directly from the practice at large mines where many of the operators and most of their miners received their training. The routine sampling at most large mines is a variation on chip sampling, but: (1) the sample-taking actually is not as haphazard as it seems to be; (2) the number of samples taken is so large that minor errors in individual samples tend to balance out, and (3) the people charged with evaluating the sample data have had such a backlog of experience with the ores of that particular mine that major errors are recognized as such and factored out quite satisfactorily. Not so for the small mine. If the mine is young there is no great backlog of information, and for old mines such data are missing or of uncertain reliablity. Then too, the operator is generally loath (and rightly so) to shoulder the expense of taking hundreds or thousands of samples when a relatively few properly located and cut samples will do the job. So, for the small-mine operator, rule number one is 'never take chip samples'.

Then there is the grab sample which, true to its name, is simply one or more pieces of ore that are 'grabbed', usually from the muck pile or the dump. It hardly seems necessary to expound on the inadequacy of the grab sample. The only ore body for which a grab sample could be expected to give satisfactory results would be one that is completely homogenous throughout. Car sampling is a variation on grab sampling that can produce satisfactory results under certain circumstances. Car samples are samples that are taken from the ore cars before or while they are being dumped. The usual implement is a shovel or fair-sized scoop, and the procedure is to take one or more shovelfulls from each car as it passes the sampler. Although one scoop per car may suffice for fairly homogeneous ores, a better method is to take one scoop from the center and two more at opposite corners. In any case, where car samples are taken, certain precautions should be observed. First, whatever the size of the sample, the same amount should be taken from each car. Second, coarse and fine material should be taken in the same proportions as they occur in the ore. And finally, crush the whole sample to the same (—¼ inch) size **before** reducing its volume for assay.

There is a fine body of information available in regard to the size of sample that must be taken to provide a representative sample of material of a given size. The writer has no quarrel with the mathematics of such derived formulas, but the size indicated is too large to be practical. For example, in the average mine the ore will range in size to blocks as much as a foot across. In theory, the minimum sample of such material should weigh 100 tons, or roughly six times the weight of the entire round being sampled. Car samples if properly taken, however, are large. For an average 5-foot round the sample would come to 150 to 300 pounds of rock ranging from sand size to large blocks. Such a sample must be reduced to manageable proportions before being sent for assay, but this cannot be done accurately in its present condition. If you must take car samples invest in a small (laboratory size) crusher to crush the sample to —¼ inch size and **then** split it down to normal sample size (a pound or two). So rule number two is, 'never take grab samples, and take car samples only if you have the facilities and the ambition to do the job properly'.

Finally there is the channel sample. Some people seem to think there is something mysterious or tricky about channel sampling. There is not, unless the expenditure of a little effort can be considered mysterious or tricky. A channel is simply a groove or trench of reasonably even proportions that goes all the way across the ore, vein zone, or whatever is being sampled. In the strict sense, the term is applied to channels cut across veins, but a trench dug across a mine dump or an outcropping vein, a pit dug to bedrock in a placer deposit, or the core or cutting, or both, from a drillhole are channels too, in a broader definition of the term. All of these meet the qualifications in that they are a continuous sample from top to bottom or side to side of the ore and are roughly of equal width and depth throughout.

The advantages of channel samples should be immediately apparent. First, if properly cut, they virtually eliminate the old question as to whether proper proportions of rich and lean ore have been taken. Second, for channels cut underground or by drill, they are initially of manageable size and need not be reduced until fine ground for assay. Pit and trench samples, of course, will be bulky. So the third rule of sampling is 'always cut channel samples unless there is a very good reason for doing otherwise, and there are few reasons that good'.

A few rules should be followed in cutting channel samples. First, always clean the surface to be sampled before cutting the sample, in order to eliminate loose pieces that could fall into the sample while you are cutting it and thereby contaminate or 'salt' the sample. Many metals tend to precipitate on the walls, back, and floor of mine workings, with time, and even freshly broken faces will be covered with powdered rock and mineral. This powder is more often than not composed mainly of ore mineral and can effectively upgrade the sample if not removed. Second, take pains to catch all of the sample. This can be accomplished by spreading a large canvas on the floor (after barring down loose pieces) beneath the place where the sample is to be cut. In very wet mines the canvas can be raised above the floor on old powder boxes, a mucking pan, or even on a folding cot. Third, cut the sample to even width and depth throughout, say 4 or 6 inches wide and 1 inch deep. Larger channels make unnecessarily bulky samples and smaller ones are difficult to keep even. The tools needed are a 3- or 4-pound hammer (singlejack) and a well-tempered moil. A chisel bit will work well in soft ore, but the pointed moil is the best in moderate to hard rock. Fourth, unless you enjoy mathematics, always cut channels either vertical or horizontal, not at some inclination between the two. And finally, unless ore is to be hand sorted or resued, always cut the sample to the mining width. In general, the minimum width that can be mined is about 3 ft., so if the vein were only 6 in. wide the sample would still be cut to a minimum of 3 ft. For veins that are wider than the minimum mineable width the general rule is to cut the sample to the full vein width. Exceptions to this would be where it is desired to determine whether a part of the vein is barren and should be (and can be) left unmined, and for special studies of ore occurrence and genesis.

There are some who will object to this last rule, and will say that only the vein should be sampled, or that vein and waste that must be mined with the ore should be sampled separately. In reply, the writer will admit that there are excellent methods of calculating ore reserves from samples of vein matter only or from separate samples of ore and waste. For that matter, there are also excellent methods for calculating reserves from channels cut at an angle from the horizontal (or vertical in the case of flat-dipping veins), but the purpose of this handbook is to present the simplest and most nearly foolproof method, and the horizontal or vertical full-mining-width sample method is far simpler and less subject to error because the number of mathematical computations is considerably reduced, thus reducing the number of opportunities for mistakes.

Some examples of sample channels are shown in Figure 2-1.

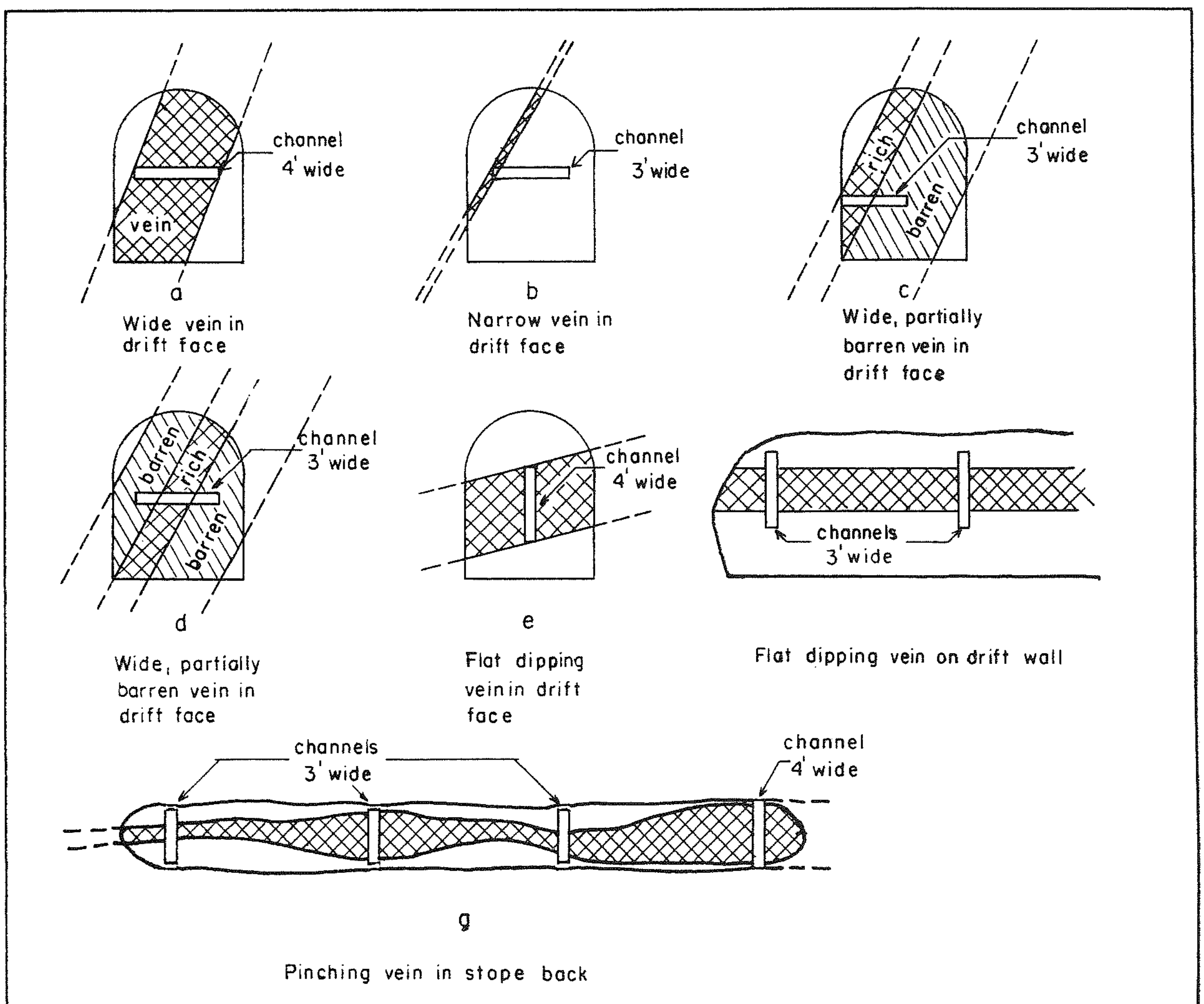

FIGURE 2-1.—Sketch showing methods of channel sampling.

Use of drillhole samples as channels requires special consideration. By and large, drillhole samples will comply with the general rule that channels should be cut either horizontal or vertical. Occasionally, however, it will be desirable to drill inclined holes in order to reach the 'target' in the shortest possible distance, or to intersect the vein at right angles so as to reduce the possibility that the drill will be deflected and follow the vein rather than cross it. In inclined drill holes, provided you take care to direct the hole so that it will be perpendicular to the vein being tested, the observed width of mineralized vein can be converted to a horizontal or vertical component by a procedure similar to that described for surveying in Chapter 1. For example, if 9 feet of vein was observed in the core of a drillhole that was inclined 35°, the horizontal width would be 9 feet $\div$ cos 35° = 9 $\div$ .819 = 11 feet. The vertical component would be the observed thickness divided by the sine of the drillhole inclination or 9 $\div$ .573 = 15.7 feet. Unfortunately, if the drillhole is not perpendicular to the vein the computation becomes enormously more complicated and for most people can be resolved most easily by a construction similar to that used in making longitudinal sections (Chapter 1) in which both vein and drillhole must be plotted at their apparent inclinations (Fig. 1-18). Horizontal and vertical components can then be measured at the scale used in the section view.

In general, drillhole samples are less reliable than normal channel samples. A part of the sample, especially the heavy ore minerals, is likely to remain in the hole despite the most careful washing, thus lowering the grade of the sample. Conversely, soft material may spall off the perimeter of the hole and add itself to the sample. Such addition of material may be either ore mineral or waste. When a core drill is used there is always some loss of core, possibly more than half. Finally, because you cannot see exactly where the drill is going and what it is doing, there is an area of doubt regarding the sample.

A considerable body of theory has been developed to allow proper weighting of drillhole samples to take account of the various ways in which the sample may have become salted. Each of the derived methods will work satisfactorily under the specific circumstances for which it was devised (usually a specific mine), but none of them can be followed blindly. For the small-mine operator, the best procedure is one that will provide reasonably accurate results most of the time, and where there is error will weight the odds in favor of a conservative assay. After all, if you must be in error it is far better to underestimate the ore body slightly than to overestimate it.

When drilling with a jackhammer, drifter, wagon drill, or other equipment that provides a sample composed entirely of cuttings and sludge, save all of the cuttings from the ore structure. Even when drilling through waste, the returning sludge should be checked every foot or so unless a considerable distance of 'known' waste is to be penetrated before the ore zone is reached. Even so, start checking the sludge well before the intersection with the vein is expected, especially if vein and wallrock are not easily distinguishable, such as quartz veins in granite or other quartz-rich rocks. At the first sign of vein matter in the cuttings, shut the drill down and wash the hole out thoroughly. Then proceed with drilling, allowing all cuttings to pass into a launder to settle. Drill slowly and wash the hole out regularly so as to be able to recognize the end of the ore or vein. When barren rock is again reached, wash the hole thoroughly again and then allow the entire sample to settle in the launder(s). If the resulting sample is overly bulky it can then be reduced by passing it through a mechanical splitter (Jones splitter) one or more times.

By calculating the volume of the drillhole, and from that, the weight of rock that should have been recovered, it is possible to determine roughly what percentage of the sludge has been recovered. Unfortunately, this will not tell you whether the missing or extra material was ore or waste, and there is no really satisfactory way to determine this, other than experience with the ore of the particular mine or district. In general, ore minerals are heavier than the gangue and if recovery is less than 100 percent most of the loss will be ore and the sample will assay low. On the other hand, most ore is softer than waste (there are exceptions) and if the recovered sample is obviously too large, it has probably been salted with ore mineral and will assay too high. If the sample is approximately the correct size, then accept the assay at face value (it is probably a little low). If the sample is clearly too large, assay it anyway, but do not place much confidence in the result unless experience in the mine indicates that you can, or unless it provides a suitable factor for correction.

When sampling by core drill, save both the core and the sludge. In the unlikely event that 100 percent of the core is recovered, the core can be used for the sample and the sludge discarded. When recovery is less than 100 percent, measure the length of core recovered and calculate the percentage of recovery, e.g., 8 ft. of hole drilled and 6.5 ft. of ore recovered:

$$6.5 \div 8 \times 100 = 81.2\%$$

Weigh both the core and the sludge (after it dries) and then assay core and sludge separately. Usually the core is halved in a core splitter, and one half assayed and the other half retained for permanent record. If the core and sludge assays agree, fine. If the core assay is higher, then it can be assumed that most of the missing core was waste. Correct the core assay to 100 percent, assuming the missing fraction to be barren, e.g., from the previous example of 8.12 percent core recovery and a core assay of 3 percent copper:

3% × .812 = 2.43% copper

If the sludge assay is higher, then it can be assumed that the nonrecovered core was in ore. In this case it is best to balance the core and sludge assays by weight, e.g., recovered core weighs 25 lb. and assays 3 percent copper, sludge weighs 64 lb. and assays 4.7 percent copper:

Core:	25 lb.	× 3.0	=	75.0
Sludge:	64 lb.	× 4.7	=	300.8
	89			375.8

375.8 ÷ 89 = 4.2% copper

The above procedure will provide an accurate assay of most drillholes. Where there is error, it will tend to be on the conservative side.

CALCULATING RESERVES IN PLACER DEPOSITS AND OTHER SHALLOW HORIZONTAL BODIES

Thin unconsolidated placer deposits are most easily sampled by a series of pits or auger or churn-drill holes dug to bedrock. Thick or consolidated (cemented) deposits may require heavier equipment. In any case, vertical holes dug or drilled to bedrock are the basis of ore estimate. In most placer deposits, the gold or other valuable mineral that is of interest is concentrated at and just above the bedrock. Some placers have a 'pay streak' between the surface and the bedrock, and some may have several 'pay' zones. As all material from the surface down to the bottom 'pay' must be moved in order to mine the deposit, the sample should effectively establish the grade of ore for the entire thickness. The safest way to accomplish this is to take the entire content of the pit or drillhole as a sample, dividing it into parts of manageable size if need be. This should always be done for samll thin deposits. For thick deposits, where the sample becomes uncomfortably large, clearly barren rock near the surface can be discarded, but the resulting assay must be corrected to true thickness. This is done, as with incomplete core samples, by multiplying the value by the percentage of the total thickness that was submitted for assay. To give a complete example, suppose that a pit 9 feet deep is required to reach bedrock. The upper 6 feet (2 yards) is barren. Panning of the bottom 3 feet recovers free gold that weights 0.1 oz., and assay shows that the gold is 800 fine (80 percent gold and 20 percent silver). Therefore, recovered gold from the bottom yard is 0.1 × .8 = 0.08 oz. The amount of silver can be ignored, as it won't affect the value significantly. As three yards were excavated to reach bedrock, the value indicated must be divided by 3; so 0.08 ÷ 3 = 0.0266 oz./yard, and if gold were selling for $150/oz., the placer material sampled would be valued at 150 × .026 or $3.99/yard.

Test pits or drillholes should be spaced evenly over the deposit if possible, as the calculation of tonnage is easier. It is also a good idea to space samples at distances that are an even multiple of a yard, again to simplify calculation of tonnage. This is because placer reserves are normally calculated in terms of cubic yards rather than tons.

Before deciding upon a sample spacing, a careful look at the geology of the deposit is in order. Placer minerals will be concentrated at points where stream velocity is reduced, or where natu-

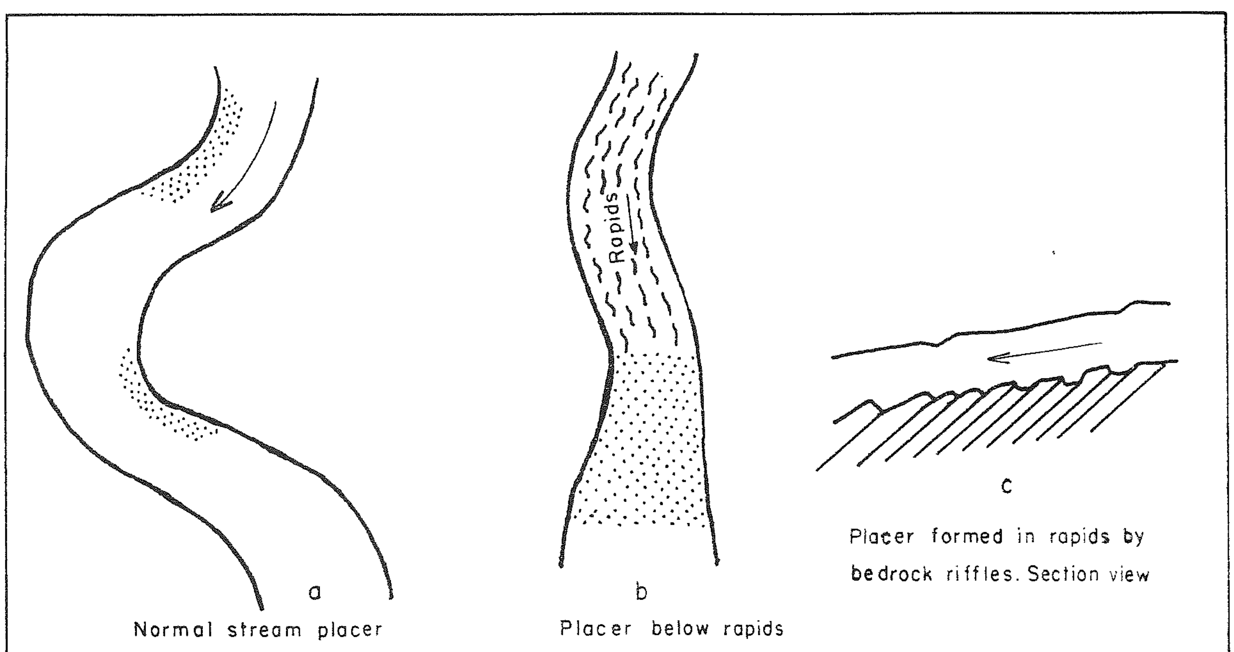

FIGURE 2-2.—Sketch showing likely places for gold concentration in streams.

ral obstacles or riffles entrap the heavier particles. Thus, the 'pay streak' can be expected to follow a gently curved line following the inner margin of the present stream course, or at the foot of rapids, or along the rapids proper if they form a natural trap. Examples are shown in Figure 2-2.

The gently curved swings of a stream that occupies a valley that is several times as wide as the stream are called meanders. In the course of time the stream will normally erode away the obstructions presented by its meanders, and as a result, its course is constantly changing. Thus, placer concentrations may underlie an entirely different part of the valley than that occupied by the stream at the present time. Therefore, it is wise to take samples all the way across the valley at intervals in order to locate older placer accumulations that may be present.

Another feature of most placers that affects the sample spacing is the greater variation in value across the stream than along its course. Thus, samples across the channel should be much more closely spaced than they need be along the length of the valley.

The final pattern of samples should be determined by results as sampling progresses. First samples can be widely spaced along the course of the deposit, say 100 or possibly 200 yd. apart. Across the channel the spacing would be narrower, say 50 yd. or 25 yd. in a narrow valley. Figure 2-3a shows the first sample locations in a hypothetical deposit. Holes are spaced 100 yd. apart along the length of the claim and 50 yd. apart across the channel. Figure 2-3b shows the location and relative value of second-stage samples spaced at 25 yd. across the channel, but still at 100 yd. along the length of the claim. Figure 2-3c shows the final spacing. Note that only those holes that are indicated by previous results are dug and that a 30 percent saving in total samples has been gained by this procedure. The presumed outline of the 'ore body' is shown by dotted line.

Beware of using old data on placers. It is unwise ever to use assay data that are supplied by someone else, or if you do, do not place much confidence in the values indicated. Occasionally, however, it may be desirable to use old data for a preliminary check of values before entering into a costly sampling program. Although most placer

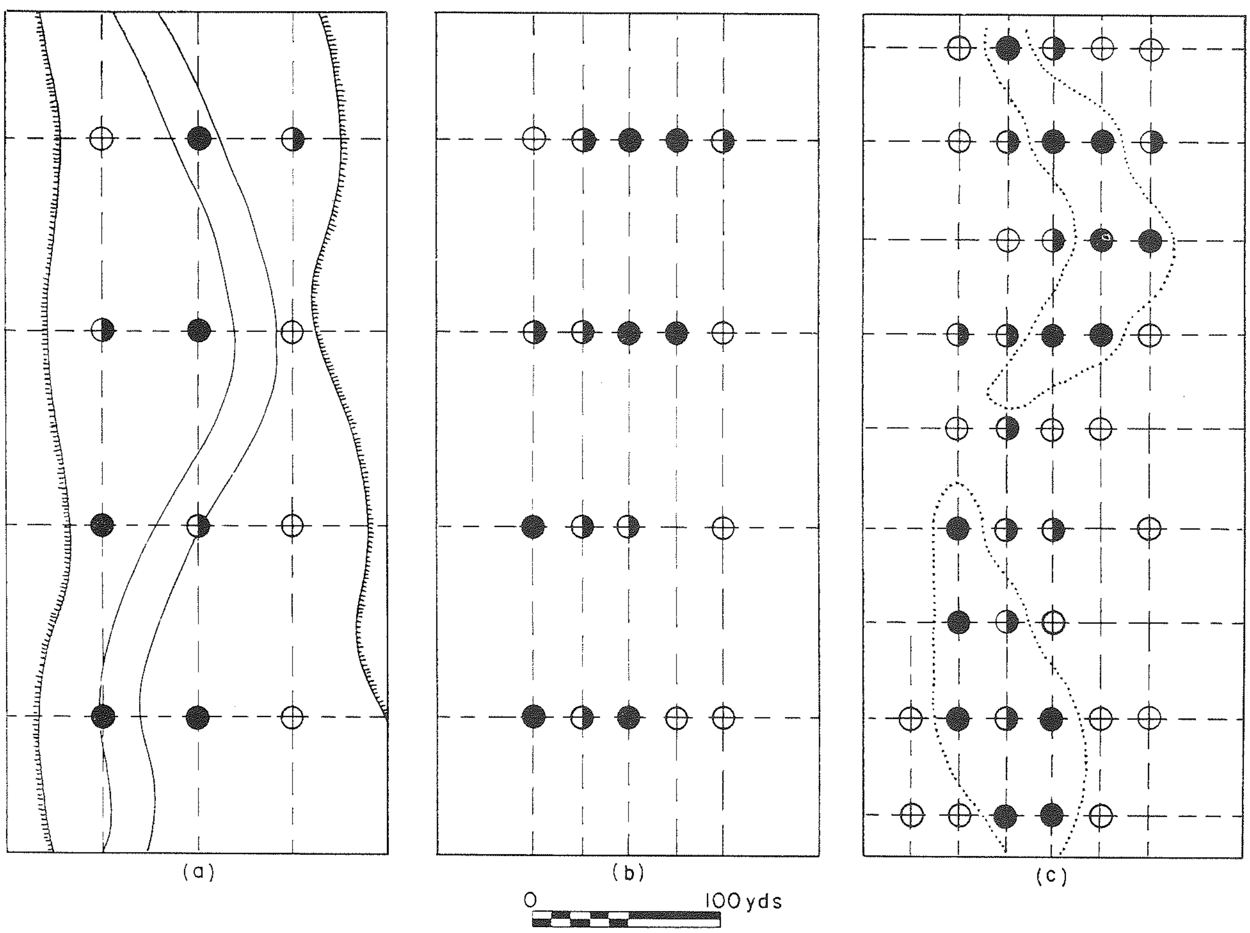

FIGURE 2-3.—Diagram of sampling layout. Circles indicate sample locations; black circles show good values; half blacked circles are marginal values; white circles show no value or only a trace. (a) Shows the first sample spacing; (b) secondary sampling based on (a); (c) final sample spacing, the limits of 'pay gravel' as inferred from sampling shown by dotted lines.

assays will be given in cubic yards, some may be given in so-called 'bedrock yards', that is, 1 sq. yd. on bedrock and as thick as the deposit may be at that point. Unfortunately, the difference is not always clearly indicated. For example: gravel valued at $1.00 per bedrock yard and 2 ft. thick would be worth $1.50 per cubic yard. The same assay on gravel 5 ft. thick would indicate $0.60 per cubic yard.

Finally, we come to the process of estimating the size and grade of the deposit. Examination of Figure 2-3c will show that where adjacent samples have indicated ore and marginal mineral value, the ore-waste boundary has been drawn half way between the two samples. Where adjacent holes show ore and waste, the boundary has been drawn one-third of the distance from the ore sample to the waste sample. This is done on the assumption that values will vary more or less evenly between samples, and the ore samples bounded by known waste are viewed somewhat less optimistically than those bounded by mineral of marginal value.

Now, if the samples have been taken on a symmetrical pattern as suggested, the area can be broken down into a series of rectangles and triangles by connecting the sampling points by straight lines. The thickness of each block is assumed to be the average of the thicknesses at its corners, and its unit value the average of values at the corners, each multiplied by the thickness at that point. Figure 2-4a, b shows two examples, one a rectangular area between four sample points, and the other a triangular area between three sample points. Note that the area of a rectangle is its length multiplied by its width, and that of a triangle is its length multiplied by its width divided by two.

The following calculations would be made for area (a), the rectangle:

Area:	25 yd. × 50 yd. = 1,250 sq. yd.
Thickness:	1.33 yd.
	.50 yd.
	1.00 yd.
	.66 yd.
	3.49 yd. ÷ 4 = .87 yd.
Volume:	1,250 sq. yd. × .87 yd. = 1,087.5 cu. yd.
Average value:	1.33 × .18 = .2394
	.50 × .20 = .1000
	1.00 × .21 = .2100
	.66 × .14 = .0924
	3.49 .6418 ÷ 3.49 = .184 or 18.4c/yd.

For the triangle, area (b), the following would apply:

Area:	25 yd. × 50 yd = 1,250 sq. yd. ÷ 2 = 625 sq. yd.
Thickness:	1.66 yd.
	.50 yd.
	.66 yd.
	2.82 yd. ÷ 3 = .94 yd.
Volume	625 yd. × .94 yd. = 587.5 cu. yd.
Average value:	1.66 × .16 = .2656
	.50 × .14 = .0700
	.66 × .12 = .0792
	2.82 .4148 ÷ 2.82 = .147 or 14.7c/yd.

Another example can be given for an area bounded on one side by ore and on the other side by waste. Such a situation is illustrated in Figure 2-4c. In this situation, the value is assumed to remain constant to the edge of the deposit (in this case ⅓ of the distance between samples); whereas thickness is assumed to decrease to zero at the edge of the deposit. For Figure 2-4c the computation would be:

Area:	8.3 yd. × 50 yd = 415 sq. yd.
Thickness:	2.00 yd.
	1.00 yd.
	3.00 yd. ÷ 4* = .75 yd.
Volume	415 yd. × .75 yd. = 311.2 cu. yd.
Average value:	2.00 × .20 = .400
	1.00 × .25 = .250
	3.00 .650 ÷ 3 = .217 or 21.7c/yd.

*Note: Total is divided by 4, even though there are only two samples, the other two being assumed to be zero.

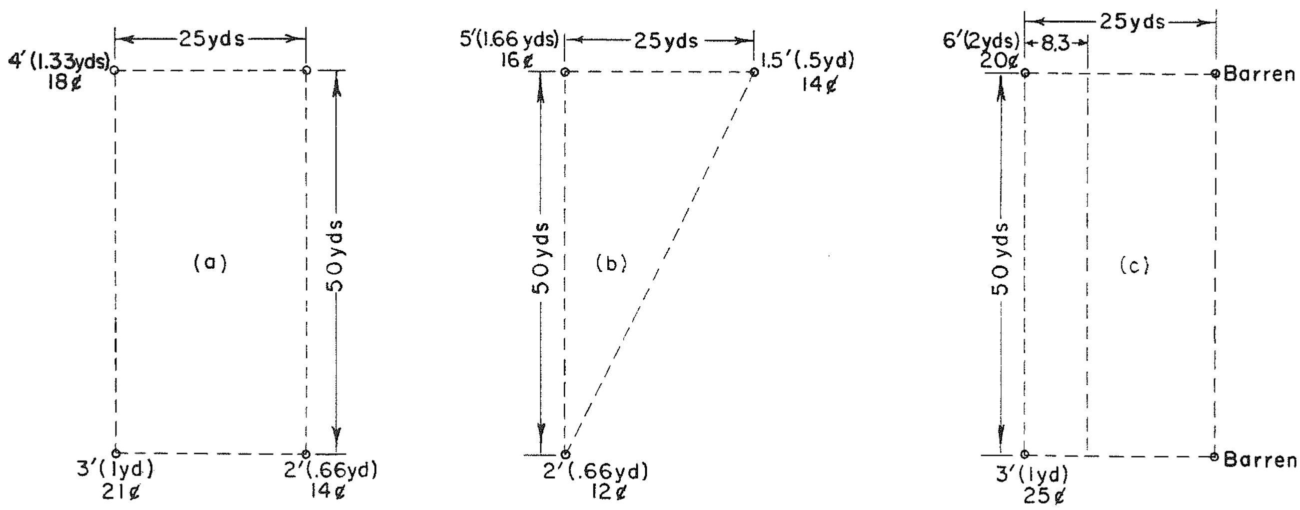

FIGURE 2-4.—Examples of blocks used in placer-deposit ore-reserve calculations.

As a final example, the lower (southern) ore area from Figure 2-3c will be calculated. This block is shown in expanded view with thicknesses and values in Figure 2-5. The yardage and grade estimate is summarized in Table 2-1. The reader would do well to repeat the calculations to make certain that the method is understood.

Areas e, f, and j are not true rectangles, as one side is longer than its opposite. For these areas, the two unequal sides are averaged and the average value used in calculating the area and volume. Also, four small triangular areas have been omitted from the calculation (between f and j, j and n, n and m, and m and i). These areas could have been added to the calculated reserve, but they are too small to make much difference (actually about 90 cu. yd.) so they can be left out as a small factor of conservatism in the estimate.

Readers who have had a considerable background in mathematics will have observed that there are technical inaccuracies in the method of estimation given. Again, this is done because this manual is intended to give the simplest and most workable procedures without going into unnecessary technical areas. The errors inherent in the method presented are far smaller than the normal range of error that can be expected in any estimate based upon so few data anyway.

If the sample pattern is not evenly spaced, as suggested, greater errors will result, and the degree of error will increase as sample spacing becomes more irregular. Therefore, unless you are competent to deal with the geometry of irregular solids you are strongly urged to sample on a rectangular grid.

There is one final advantage to be gained by calculating reserve blocks in tabular form as has

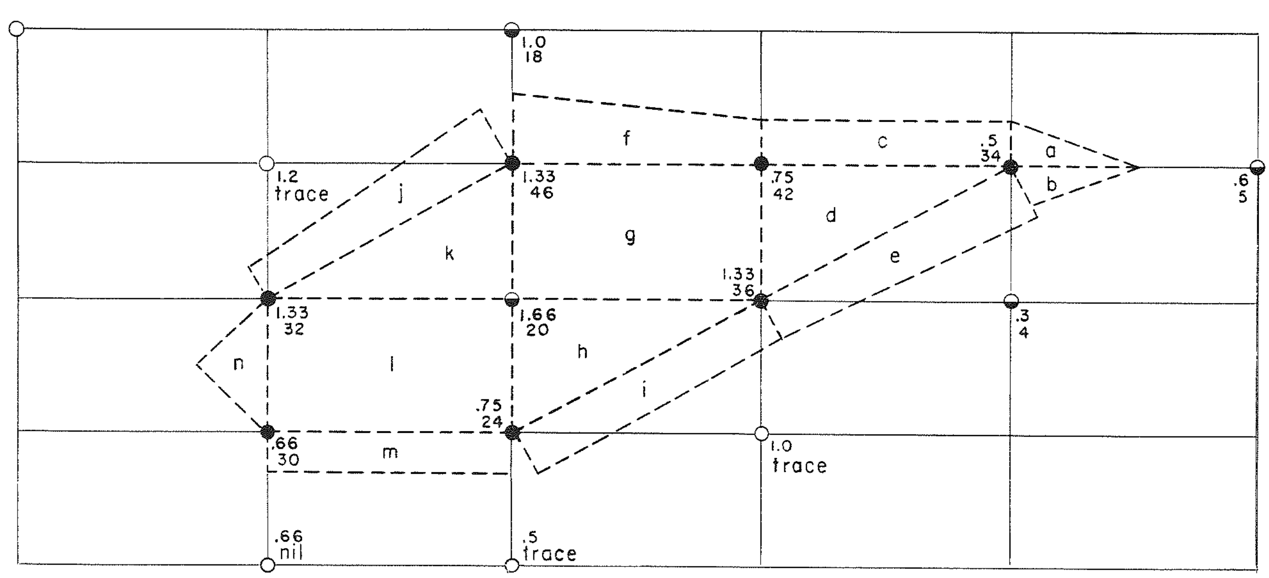

FIGURE 2-5.—Placer ore block from Figure 2-3. Thickness (top number) is shown in yards and value (bottom number) in cents per yard. Individual small blocks are designated by letters to distinguish them in calculation.

TABLE 2-1.—Yardage and grade estimates for placer problem.

Block	Area	Average thickness	Volume	Average value	Vol. x Val.
a	104.1	.25	26.02	.340	8.846
b	104.1	.25	26.02	.340	8.846
c	416.5	.31	129.11	.388	50.094
d	625.0	.86	537.50	.374	201.024
e	572.5	.46	263.35	.354	93.226
f	520.5	.52	270.66	.444	120.172
g	1250.0	1.27	1587.50	.342	542.724
h	625.0	1.25	781.25	.214	206.250
i	458.1	.52	238.21	.316	75.274
j	572.5	.66	377.85	.390	147.360
k	625.0	1.44	900.00	.316	284.400
l	1250.0	1.10	1375.00	.258	354.750
m	416.5	.70	291.55	.260	78.134
n	208.2	.66	137.44	.314	43.156
Total			6941.86		2214.256

Total volume = 6941.8 cubic yards
Average value = 2214.256 ÷ 6941.86 = .319 or 31.9 ¢/yd.

been done in Table 2-1. If the overall average of the block should prove to be below ore grade, it is a simple matter to eliminate low-grade subblocks from the table (e.g., blocks h and l) and bring the rest up to ore grade. (Elimination of blocks h and l lowers yardage to 4785.61 cu. yd. and raises grade to 34½¢ per yd.) These marginal or submarginal blocks can then be held in reserve, unless their location forces you to mine them anyway at a loss, and they may be mineable at a later date under more favorable market conditions (calculations are based on a gold price of $35/oz.).

Many deposits other than placers can be dealt with by following essentially the same procedure outlined above. For example, secondary uranium deposits, sedimentary iron deposits, coal beds, and many nonmetallic minerals such as clay, bentonite, and phosphate, can be sampled and reserves estimated in this way provided only that the deposits are horizontal or nearly so and near surface (within economically feasible drilling distance). In general, sampling must be done by drill hole rather than test pit, but the principle is the same. Also, values will usually be reported in percent or value per ton rather than ounces or cents per cubic yard, but the conversion is simple.

CALCULATING RESERVES IN VEIN DEPOSITS

The process of estimating reserves of vein deposits and of other inclined tabular bodies is essentially the same. The fact that the vein or ore is at least partly exposed in drifts and raises offers some advantage over placer deposits, which rarely enjoy such exposure. Vein deposits are notably erratic in their behavior, however, a fact that more than compensates for any advantage of exposure. The process of estimation, then, involves not only the calculation of volumes and the weighting of assays, but the application of rules of probability and a good deal of judgment on the part of the estimator.

The first requirement is a set of accurate longitudinal sections. One long section should be prepared for each known vein. Structure and lithology need not be shown on these sections, provided that other sections with the known geology are available and can be placed under the ore-reserve section so that both geology and mineralization can be viewed at once when needed. In fact, it is generally a good idea to maintain separate geology and ore-reserve long sections, as this prevents either sheet from becoming so cluttered with data as to become difficult to read. Even on 'raw' prospects where the only available information is from vein outcrops at the surface, a longitudinal section should be prepared showing the surface topography in section view and all vein outcrops. Even this little bit of information will help in estimating the potential of the prospect. Actual estimation of ore reserves of a new prospect is a fool's errand and should not be attempted except to aid in deciding whether the cost of further exploration is warranted.

The second requirement is an adequate number of properly spaced and cut samples. The proper cutting of samples has already been discussed in a previous section of this chapter. Proper spacing of samples in vein deposits will vary widely from one deposit to another. As a rule, the greater the unit value of the metal in the deposit, the closer the sample spacing must be. Thus, gold and silver veins require closer sample spacing than lead, zinc, or copper. Then too, the mode of occurrence is important. Native gold that occurs in a quartz or other valueless gangue requires the most rigorous sampling procedure, whereas gold that is disseminated within pyrite grains, although still requiring a close spacing, will generally allow a little more 'projection' between samples. The same is generally true of silver, either in the native state or in discrete grains of one or more of the high-grade silver minerals as opposed to silver that occurs intimately associated within another less valuable mineral such as some of the silver-bearing lead or copper minerals. Of course, these are generalities, and there are numerous deposits that prove to be exceptions to the rule, as there are for virtually any rule that man can devise.

Unless the mineralization of a vein deposit is remarkably constant, and in addition is such that its grade can be judged visually with reasonable accuracy, a 25-ft. sample spacing would be a maximum for safe estimation of reserve. The average spotty base-metal vein will require samples spaced 10 to 15 ft. apart, and many gold and silver veins require samples spaced as close as 5 ft. Fortunately, most veins contain considerable stretches that are so obviously barren or submarginal that normal sampling becomes unnecessary. Even so, occasional samples should be taken in these barren or nearly barren zones as a check. They may contain valuable mineral in a form that has thus far gone unrecognized, or they may provide important information on the gradation of mineralization intensity. Needless to say, samples should be cut at regular intervals in stopes and raises, as well as along drifts.

Whatever sample spacing is decided upon, samples should be taken at precisely the same interval along the drift all the way across the mineralized area. There are several reasons for this precision: (1) the obvious one that it will simplify subsequent calculation, (2) it eliminates the possibility that sample locations that are consistently either richer or leaner than the average may have been selected, and (3) it provides a check on the adequacy of sample spacing. If sample spacing is sufficiently close to provide reliable results, then a second set of samples taken halfway between those of the first set should give the same average value, within reasonable limits.

The ability to check on sample-spacing adequacy is particularly important when one or more samples in a series show an abnormally high value. Such 'erratic highs' are always bothersome. They unduly raise the estimated grade (when accepted at face value) if they are really erratic. On the other hand, if they actually represent true variations in the ore grade they certainly should not be discounted. There are mathematical approaches to the handling of erratic results, and these formulations can be applied with excellent results to problems in human behavior, machine production, engineering design, and a host of other applications. All such formulations, however, are based on the assumption that there is some logical, recurrent, or normal function involved, and therefore, deviations from this norm are measurable. Unfortunately, it has yet to be proved that there is any such thing as normal behavior for a vein, and it seems unlikely that such will ever be proved. The standard deviation method will work satisfactorily in evaluating results of samples for most low-grade base metal ores. That is, erratic highs that exceed the mean plus three times the standard deviation can be reduced to the average of other samples. The resulting estimate is usually satisfactory. This method will not be presented here, however. A more direct approach to the problem would seem desirable for the average small mine.

For example, let us suppose that a gold-quartz vein is being sampled. The strike length of the mineralized zone is 100 ft., and samples are cut at 5-ft. intervals, or 21 samples in all. Twenty samples average 0.15 oz./ton in gold, and assays range from 0.1 to 0.3 oz./ton. The other sample assays 6.5 oz./ton. If this sample is included in the calculation it raises the average for all samples from 0.15 to 0.45 oz./ton, or at a gold price of $150/oz., from $22.50 to $67.50/ton. Obviously the difference is too large to be ignored.

If we assume that the sample channel is 3 ft. long and 1 by 4 in. in cross section, it is found that the resulting high assay would result from the presence of one or more nuggets that together have roughly the size of a BB. Immediately four possibilities present themselves. They are: (1) there has been an error in the assay; (2) the sample is erratic (abnormal) and should be ignored; (3) such high-grade areas occur more or less at random throughout the deposit, and the sample value should be retained; and (4) the sample in question marks the location of a high-grade 'shoot' in the vein. The first possibility is easily checked, assuming the assayer is competent, and provided that you have requested that all reject pulps be kept for possible re-assay (which you should always do). If it is an assay error, the re-assay will show normal values. If not, the re-assay will show a similarly high value, although a perfect check would not always be expected on ore of such high grade, so the correct answer is one of the last three listed. Under these conditions, the first impulse is usually to re-cut the sample only 1 in. deeper, but this practice defeats its purpose in two ways: (1) if high values are randomly distributed the re-cut sample will almost certainly assay low, thus indicating that the original sample was abnormal; and (2) if the high assay is repeated, you are still in doubt as to whether you are dealing with a chance pocket of high-grade or an ore shoot.

A better approach is to cut a new series of samples spaced halfway between the samples of the original series, or 2½ ft. from the sample on each side. Now, if the new series shows more or less consistent values averaging say 0.12 to 0.17 oz. then it must be concluded that the one assay was abnormal and it is reduced to the average

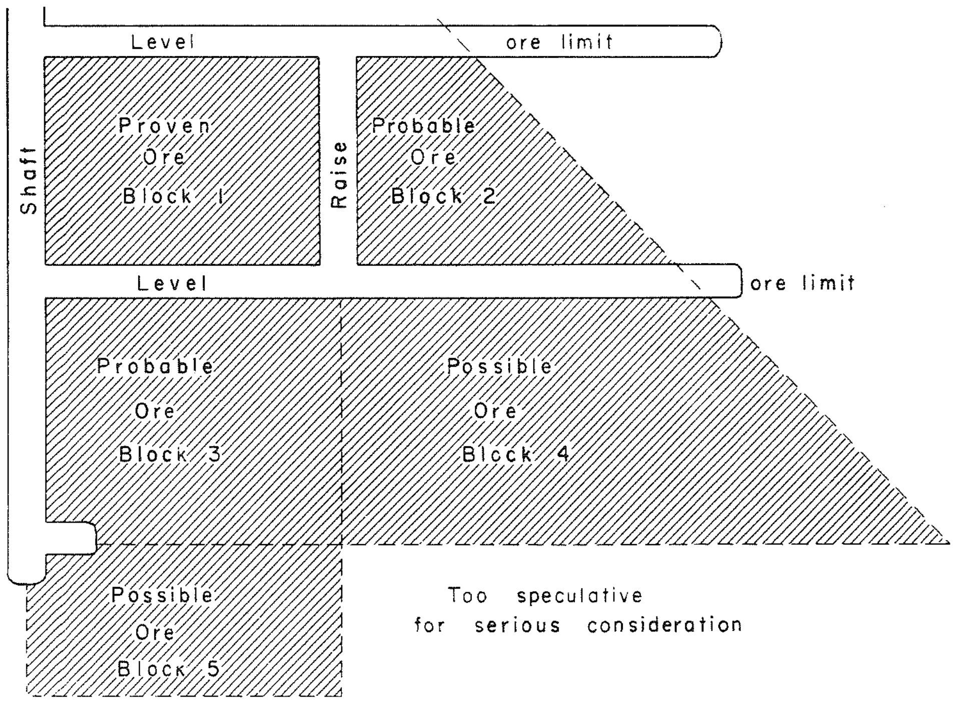

FIGURE 2-6.—Long section illustrating classes of ore reserves.

of the other samples (now 41 in number) for calculations. If high values are randomly distributed in the deposit, one or more samples in the new series should show an abnormally high value, although not necessarily so spectacularly high as the first example, say 1 oz. or more. If this happens, then it is assumed that all samples are normal and they are accepted at face value. If high values, again not necessarily as high as 6 oz., occur in samples cut adjacent to the original high-value sample on one or both sides, it is concluded that a high-grade shoot is present. Say for example, the sample on one side assays 1 oz. per ton, and the one on the other side 2 oz. per ton. In this case again, all samples are accepted although it might be prudent to reduce the extreme sample by one-third to avoid overoptimism regarding the values present (after all, with ore like this, why quibble?). Following this procedure has provided you with reasonable assurance that you have the correct relationship and value, although one can never be absolutely sure. Furthermore, you now have a larger number of samples and, presumably, a better average. Moreover, you have checked upon the adequacy of your original sample spacing and found it satisfactory.

You have now taken an adequate number of samples and checked or corrected any apparently erratic or abnormal results. The next step is to carefully plot all sample locations and values on the longitudinal sections. Then, from the known or estimated minimum grade that can be mined profitably, mark off ore areas in some suitable way. Using a color scheme is best, say using red for good ore, orange for low-grade to marginal ore, and green for ore that has already been mined.

The next step is to project probable ore limits between levels and raises on the basis of the best information at hand. Three classes of ore must be considered. First there is ore known variously as 'proved ore', 'blocked out ore', or 'measured ore'. This is ore that has been outlined top and bottom by levels and at both ends by either raises or shafts. Ore is known to be present on all sides, and the only uncertainty involves possible pinches or horses of waste in the center of the block. The second grade can be called 'probable ore' or 'indicated ore'. Such ore has been observed on two or three sides but its extent and continuity are still somewhat in doubt. Finally, there is 'possible' or 'inferred ore', which is ore that has been exposed on one or possibly two sides, depending on circumstances, but whose extent, continuity, and grade are most uncertain. Figure 2-6 illustrates several possible situations and the grade and extent that would be assigned to each. The limits of block 1, proved ore, are selfexplanatory. Block 2, probable ore, has been limited by known waste on two levels and the block margin simply connects the two known points. Obviously, the true margin may fall on either side of the line so drawn. Block 3, probable ore, is exposed on only two sides but is ranked as probable because mineralization is known to extend to its full depth and beyond, and extends well beyond its right-hand margin. Block 4, possible ore, is exposed on one side only. In establishing the limits of this

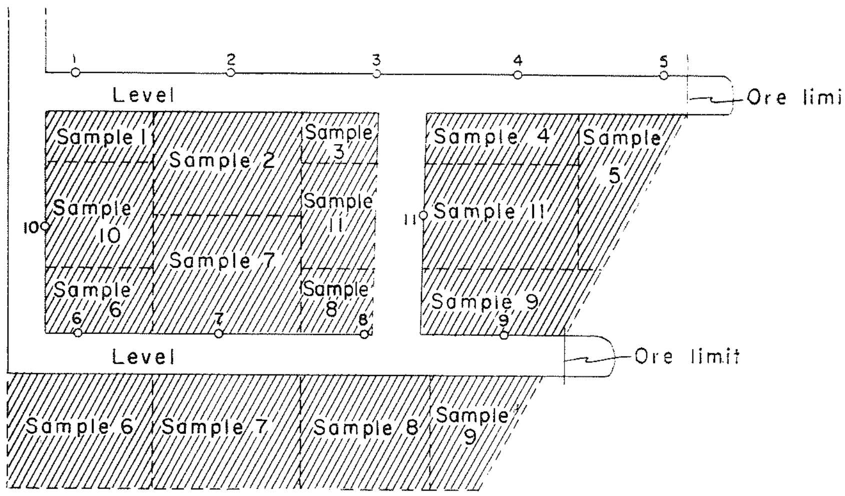

FIGURE 2-7.—Sketch illustrating area of influence of samples.

block, the apparent plunge of the ore has been projected downward and to the right as deep as mineralization is known to continue (at the shaft) but no farther. The block directly below block 4 may well be ore, but it is too speculative to warrant consideration until further development gives a more certain indication of its presence. This is not to say that this area is not a perfectly legitimate 'prospect', but only that it should not be considered in terms of reserves. Block 5, also possible ore, is extended laterally for the width of the overlying block 3 because continued mineralization to at least that width seems likely, provided it continues at depth. The vertical extent of block 5 is arbitrarily placed at one-half the distance between levels. The same limitation would be placed on a block where known waste occurred on the next level, unless other indications (in raises, winzes, etc.) indicated a more precise location.

After the ore blocks are outlined as accurately as possible on the basis of available information, each sample bordering each block is assigned an 'area of influence'. When multiplied by its measured width, this area of influence will establish the estimated volume and grade of a subblock. The area of influence of a sample extends both ways from the sample location halfway to the next sample location or to the end of the block in the case of the last sample in the series. Between levels or raises, the area of influence also extends halfway. Figure 2-7 illustrates the area of influence of samples in several blocks. The number of sample locations has been kept small so as not to clutter the illustration unnecessarily. Although the samples are spaced evenly, their areas of influence are far from even. There are numerous alternative methods for establishing areas of influence, but there is little evidence that they provide a more reliable estimate. All other methods share the common disadvantage that they are more difficult to calculate. Note also that a single sample can have more than one area of influence, e.g., samples 6, 7, 8, 9, and 11.

The next step is to set up a block-estimation

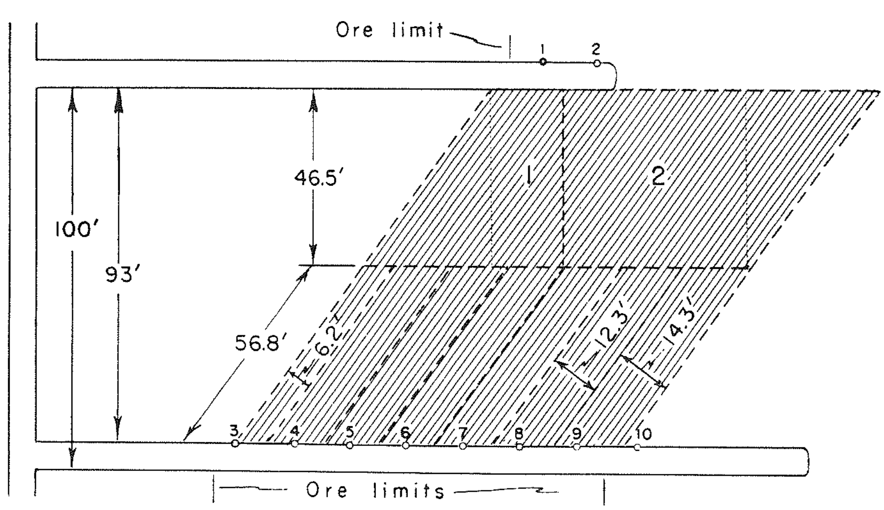

FIGURE 2-8.—Ore block estimating diagram. Sample spacing is 15 ft., net distance between levels is 93 ft., drifts are 7 ft. high.

TABLE 2-2.—Ore block estimating data.

Subblock no.	Assay val. Au	Ag	Length	Depth	Width	Volume, cu. ft.	Probability	Net cu. ft.	Ton factor	Net tons	Ton-val. Prod. Au	Ag
1	.105	1.35	18.75	46.5	3.0	4794.4	90	4314.9	10.6	407.1	42.74	549.58
			31.25/2									
2	.210	2.73	48.75	46.5	3.5	10476.2	70	7333.3	10.6	691.8	145.28	1888.61
			31.25/2									
3	.140	2.01	6.2	58.6	3.0	1089.9	80	871.9	10.6	82.2	11.51	165.22
4	.181	2.40	12.3	58.6	4.1	2955.2	90	2659.7	10.6	250.9	45.41	602.16
5	.258	3.50	12.3	58.6	3.2	2306.5	90	2075.8	10.6	195.8	50.52	685.30
6	.306	3.29	12.3	58.6	3.5	2522.7	90	2270.4	10.6	214.2	65.54	704.72
7	.218	4.22	12.3	58.6	3.3	2378.6	90	2140.7	10.6	201.9	44.01	852.02
8	.235	2.92	12.3	58.6	3.1	2234.4	90	2010.9	10.6	189.7	44.58	553.92
9	.158	2.08	14.3	58.6	3.2	2681.5	80	2145.2	10.6	202.4	31.98	420.99
10	nil	tr	—									
Total										2436.0	481.57	6422.52

Total tons = 2436

Average Au $= \frac{481.57}{2436} =$ .197 oz.

Average Ag $= \frac{6422.52}{2436} =$ 2.63 oz.

table. One table should be prepared for each block. Figure 2-8 shows a hypothetical ore block and sample locations. Sample values are shown in Table 2-2, which is a block-estimation table for the ore block illustrated. This block would be classified as in part 'probable' and in part 'possible'. Irregular areas such as 1 and 2 (Fig. 2-8) can be calculated as a rectangle plus a triangle (see dotted line). All dimensions can be measured from the longitudinal section with sufficient accuracy. Calculation of the total block indicates the presence of 2,436 tons of ore averaging .197 oz. gold and 2.63 oz. silver per ton. Most small-mine operators could mine such ore profitably if they would, but if this proved too marginal, subblocks 1, 3, and 9 could be eliminated leaving 1,744 tons of ore averaging .226 oz. gold and 3.03 oz. silver.

Two factors in the table require special comment. The 'ton factor' is similar to the yard factor of placer computations. It is necessary to estimate the number of cubic feet in one ton of ore in place in the mine. The factor used in the table would apply for a vein composed mainly of quartz containing a small amount of pyrite with gold and silver. Heavy sulfide veins will require a much lower factor. Although the ton factor can be calculated from estimated mineral percentages and the known specific gravities of the various minerals, a more practical approach is to weigh the material taken from an excavation of known dimensions. Small excavations of a cubic foot or so can be made, but they may not prove to be of average ore.

A better way is to weigh the entire product of several rounds to establish an average. Then measure the length of advance and the cross sectional area of the drift to establish volume (e.g., 5 x 7 ft. drift, 10 ft. advance = 350 cu. ft.; allow 3 ft. per foot of advance for arching of the back and you have 320 cu. ft.). Remember to weigh the material after it has dried, as smelter returns are paid for dry tons, not water-soaked tons.

The second new factor in Table 2-2 is the probability factor. Here the estimator is called upon to exercise his best judgment. Proved ore should logically enjoy a better 'probability' of actually being present as predicted than probable or possible ore. Experience may show that the ore of a given mine tends to be spotty, numerous waste areas being scattered throughout. Or the ore may tend to pinch out rapidly and unpredictably. In such cases, a lower probability would be assigned to the ore. The probability factor is simply a measure of the percentage of the measured block that you, in your best judgment, feel is likely to be present. Some estimators also apply a factor of recoverability at this point, because many mining situations will require that some of the ore must be left unmined. The writer prefers to omit recoverability from ore-reserve calculations, as it is more an operational problem than a geological one.

In the example (Table 2-2), subblocks 1, 4, 5, 6, 7, and 8 have been assigned a 90 percent probability, as they are probable ore and least subject to error. Subblocks 3 and 9 have been assigned an 80 percent probability on the assumption that the blocks on the margin of a body are more subject to pinches and changes in mineralization and value. Subblock 2 is estimated to have a 70 percent probability, because it is possible ore and because it is the most speculative of the subblocks within this block. Again, the reader would do well to go through the calculations of Table 2-2 to make certain that the method is thoroughly understood. The factor of probability was not considered in calculating placer reserves, because once the probable limits of ore are established, all gravel within the outline must be mined. Only the grade is uncertain, and this has already been established to the best of our ability.

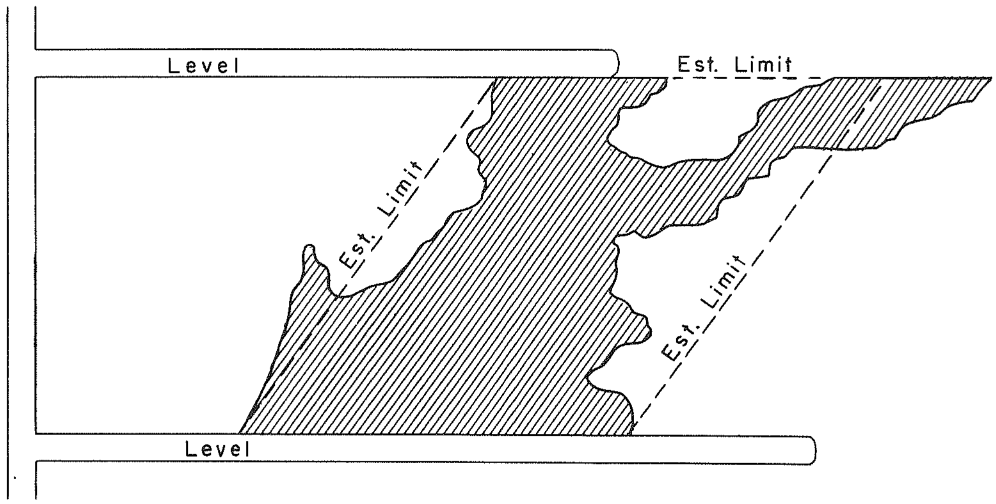

FIGURE 2-9.—Sketch illustrating hypothetical ore block.

Some estimators prefer to handle the problem of probability at an earlier stage by drawing the margins of ore blocks less optimistically in the first place. This writer prefers the probability factor method because: (1) there is no logical reason to believe that irregularly drawn ore limits will prove more accurate in the final analysis, and (2) it is almost certain to be more difficult and time consuming to estimate the area of such irregular blocks. Remember that only by the wildest coincidence would ore limits fall precisely where they were estimated to be. Most ore bodies are extremely irregular in outline and the idea is only to estimate the probable overall gross size. Figure 2-9 illustrates another hypothetical ore block based upon the one illustrated in Figure 2-8, which by design has the same size as the estimated block after reduction for probability.

Some of the recommended steps have actually saved time and effort. First, is the taking of channel samples, either horizontal or vertical and drawing longitudinal sections to true vertical depth intervals rather than inclined depth intervals. Figure 2-10a illustrates a vein dipping 50° showing true width and depth. Figure 2-10b shows the same vein projected with horizontal width and vertical depth. In both views the area is the width multiplied by the depth. Hence, the same cross sectional area is derived without the necessity for the time-consuming and often difficult measurement of channel widths at right angles to the dip and the need to convert vertical measurements to true dip extension.

The second simplifying step was to cut all samples to at least the minimum mining width. The saving here can be illustrated by taking an example from Table 2-2, the previously calculated block. Let us suppose that sample 3, which was cut to a minimum mining width of 3 ft., actually contained 1.5 ft. of vein, which if assayed separately would have contained 0.251 oz. gold and 3.60 oz.

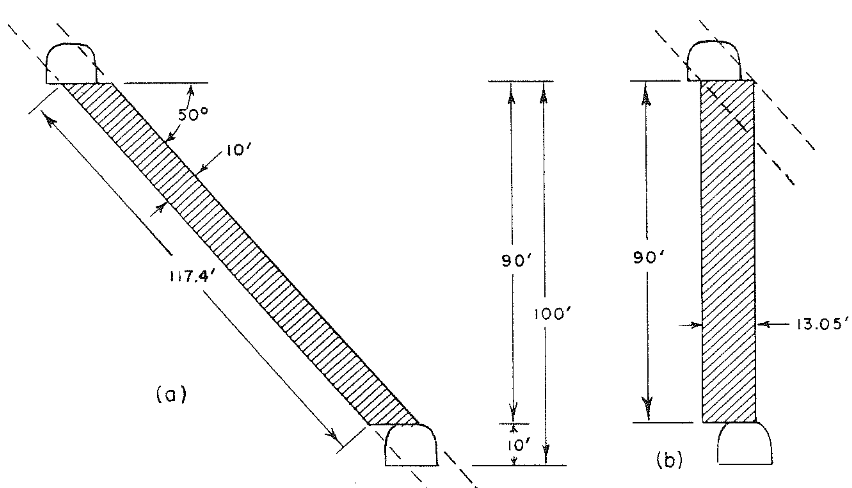

FIGURE 2-10.—Sketch showing relationship of horizontal distance and vertical height to true width and slope distance.

TABLE 2-3.—Ore-block estimating data for split sample No. 3a and 3b.

Sample no.	Assay val. Au	Ag	Length	Depth	Width	Volume, cu. ft.	Prob. Factor	Net cu. ft.	Ton factor	Net tons	Ton-val. Prod. Au	Ag
1	Same as table 2-2.											
2	Same as table 2-2.											
3a	.251	3.60	6.2	58.6	1.5	544.9	80	435.9	9.5	45.9	11.52	165.24
3b	nil	nil	6.2	58.6	1.5	544.9	80	435.9	12.0	36.3	.00	.00

Table indicates 82.2 tons averaging .140 oz. Au and 2.01 oz. Ag.

silver. In order to mine this ore, however, an additional 1.5 ft. of barren rock would have to be taken, which contains neither gold nor silver in appreciable quantities. If sampled separately, or if only the vein were sampled, this portion of the block estimation table would appear as shown in Table 2-3. A similar procedure would have to be followed for every place where the vein was less than the minimum mining width throughout the mine. In a mine, particularly one where the vein is narrow in many places, this could add up to many wearisome hours of unnecessary labor. Examination of Table 2-3 will disclose several differences. The choice of a probability factor for waste dilution can be approached in either of two ways. If the estimated missing 20 percent of ore is missing in terms of extension, then the probability of waste is the same as that of ore (the choice made in the example given). If, on the other hand, the 20 percent reduction occurs as a thinning of the vein, then inclusion of 120 percent of estimated waste would be necessary. Experience with the particular vein may offer a clue as to the proper calculation. The tonnage factor probably will require adjustment too, particularly if densities of ore and waste are very different. This possibility has been shown in Table 2-3 by calculating waste as nearly pure quartz and placing all of the 'values' in the 1.5 ft. of vein material. Note also that the assay is somewhat less than double that of a 3-ft. channel, because the material assayed is heavier although containing the same amount of valuable metal.

Finally, all reserve blocks in various parts of the mine are estimated in the same manner and the reserve estimate is complete. Final disposition of the estimates so obtained will be covered in the next section of this chapter.

ORE-RESERVES RECORDS

Ore-reserves records can most easily be kept in tabular form in a ledger book, preferably loose-leaf so that additions and subtractions can be made with ease. The reserve record serves several purposes: (1) it is a readily available record of the current reserves that can be used to project estimated profits and allowable capital expenditures for the future, (2) it will allow an easy check on whether development work is actually keeping pace with production (ton for ton) and offer a clue as to where development work can most profitably be done to maintain or achieve a balance, and (3) when completed by addition of actual production figures, it will provide information on the adequacy of sampling and reserves calculations. It can also be used, together with cost data, for more accurate appraisal of minimum ore grades and for tax computations.

An infinite variety of tabulation forms can be used, some good and some bad, but a few simple rules should suffice for setting up records. The table should be as simple as possible without omitting necessary information. It should provide sufficient data for positive identification of individual ore blocks; there should be ample provision for additions and changes in block estimates; and it should provide for carrying totals on significant items.

In a very small mine, the block estimation tables will provide adequate records, possibly with some addition of information about production. In larger mines, it is better to maintain reserve ledgers that are a summary of the information on block estimation tables.

Table 2-4 is a suggested form. Reserve blocks are simply designated by number, although in larger mines it might be necessary to designate vein or area and level as well as block number to completely specify a given block.

Books may be brought up to date monthly, bimonthly, quarterly, semi-annually, or annually, depending upon business necessity or personal preference. In any case, they should be summarized at the end of each business year.

In the normal course of events, reserves listed as 'net mineable' (Table 2-4) will move into the 'tons mined' column; those from 'long-term reserves' will move into 'net mineable'; and prospective or 'possible ore' into the 'long-term reserve'. Ideally, development work should be geared to keep the balance between tons mined per year and reserves of net mineable ore even. That is, the tons mineable column should never contain less than one year's production. This, in turn, requires that sufficient reserves (proved and probable ore) be maintained in the long-term

TABLE 2-4.—Ore reserves balance sheet.

Annual summary
Period

Date

Block no.	Tons net mineable	Tons long term res.	Tons possible res.	Est. assay Au	Ag	Cu	Tons mined	Smelt. assay Au	Ag	Cu
1										
2										
3										
4										
5										
6										
Total										

reserve to allow development of sufficient net mineable blocks as production progresses. This requires at least one year's normal production tonnage in long-term reserves at all times, and a good all-around figure would be two year's production in the long-term reserve column. If long-term reserves are maintained too far in advance of current production, however, it will lead to costly and inefficient operation, as the underground workings driven to 'prove up' these reserves must be maintained at least until the ore is mined.

The prospective or possible reserve column lists principally ore that has not actually been seen, that is, ore that is presumed or hoped for at greater depth or farther along the strike of the ore-bearing structure. Prospect drifting, shafts, winzes, or drilling should be undertaken at such a rate that new ore blocks can be developed as needed to replenish the long-term reserves. When no new ore is to be found, this prospect work can provide adequate advance warning of the eventual closing of the mine. If this procedure is followed, the mine operator should always have assurance of continued profitable operation for 3 to 7 years ahead. When the mine plays out, as all mines must, he will be forewarned in time to prevent unnecessary capital expenditures for development and for equipment that will not be amortized by production.

The estimated and smelter assay columns are provided for two reasons. First, of course, they provide an immediate check on the adequacy of sampling and reserve estimate methods in use. If smelter assays are consistently higher or lower than the estimate, steps can be taken to provide closer correlation. Then too, the smelter assay data in tabular form provide a handy source of information to be used together with cost data in evaluating the profits and efficiency of the operation.

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CHAPTER 3 — MINERAL AND ROCK IDENTIFICATION

By

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INTRODUCTION

It has been estimated (Kerr, 1959) that there are approximately 1,700 recognized mineral species. Obviously, no attempt can be made in this small handbook to provide a method of identification of all or even a large part of this great number of minerals. Instead, the tables presented here provide a method of identification for 100 selected mineral species that include the most commonly occurring ore and gangue minerals. Those readers who want to pursue the subject of mineralogy and mineral identification further will find a list of the most widely used references on the subject below.

Following the mineral-identification tables are rock-identification charts. Again the total number of rock species that are recognized by petrographers is far too large to be encompassed here. Moreover, meticulously correct identification of rock species is rarely a necessity in the mining industry. What is essential is that the rocks present be recognized as to the general group to which they belong, and in some cases, to distinguish between two or more similar appearing or closely related species. The tables provided, then, give the simplest breakdown possible, allowing a rough identification of most of the commonly occurring rock types.

Most small-mine operators will find that despite their best efforts, plus the information contained herein, there will be one or more minerals or rocks present in their deposit that they cannot identify satisfactorily. This is to be expected because many minerals and rocks require special chemical and optical study for proper identification.

To aid in such cases, many state geological surveys can be called upon to provide identification service to state residents. Geology department staff members at most colleges and universities would be willing to help if the volume of work is not too great. If many identifications are involved, a consultant may be required.

INSTRUCTIONS FOR USING MINERAL IDENTIFICATION TABLES

The tables have been arranged for the progressive isolation of mineral species through a series of four easily recognizable physical properties. Proper recognition of these four properties will indicate that the mineral in question is one of a relatively few species in a subgroup. The minerals within the subgroups are further described as to specific properties, and one or more likely diagnostic features are listed for each mineral.

The first major subdivision is to separate minerals having a metallic appearance (or luster) from those that appear nonmetallic. Thus, a mineral that looks more or less like iron, steel, copper, brass, or silver would have metallic luster, whereas one having an earthy, dull, transparent, or brightly colored appearance would be termed nonmetallic. Some minerals of doubtful luster are listed in both groups.

Next, minerals within metallic or nonmetallic groups are separated into broad color groupings. Then, within color groupings they are separated on the basis of whether they are soft (can be scratched by fingernail or a copper coin), of medium hardness (not scratched by a copper coin but can be scratched by a knife blade), or hard (cannot be scratched by a knife blade). Finally, specific criteria are given for individual minerals.

Among the important specific criteria is a property known to geologists as streak. A mineral's streak is the color of the mark it makes when rubbed on a piece of white unglazed porcelain, and for many minerals this streak color is different from the color of the mineral itself. This is a very useful property in identification, and the streak of all minerals listed has been given as an aid in identification. White unglazed porcelain can be obtained from mineral and laboratory supply companies, or if more convenient, the back (unglazed) side of an ordinary bathroom or kitchen ceramic tile can be used. In an emergency, the broken edge of a coffee cup or dinner plate will also provide a satisfactory unglazed surface.

In some instances, the tables suggest simple chemical or blowpipe tests for confirmation of mineral identity. Such tests may indicate a reaction that will occur if the mineral is placed in one or another of the common (easily obtainable) acids, or what will happen if a small fragment of the mineral is heated in the flame from a blowpipe. The blowpipe is a small metal tube (usually brass) with a drilled tip at one end. When held by a small flame (candle, alcohol burner, or bunsen burner) and blown through steadily, it will produce a concentrated, extremely hot flame. Minerals may be described as being fusible (easily melted) or infusible B.B. (before the blowpipe), or it may be noted that they expand or pop when heated, or give off recognizable fumes. In addition, simple chemical tests that are definitive of certain minerals are given in the tables, or the reader is referred to a specific chemical test for an element to identify the mineral. In the chemical tests described in the following paragraphs, care has been taken to include only the most simple and necessary tests using reagents, most of which are obtainable at your neighborhood drugstore or grocery store.

LIST OF REGEANTS AND EQUIPMENT

Equipment

Flame: The ideal flame for these tests is that produced by a bunsen burner using ordinary household gas. A satisfactory flame can be produced, however, by a kerosene or alcohol lamp, or an ordinary wax candle.

Blowpipe: The blowpipe is a simple instrument for producing a concentrated flame. It can be purchased from chemical or mineral supply houses and is available in some drug and hardware stores in mining communities. The tip of the blowpipe is held in the burner or candle flame while the operator blows gently and steadily into the other end. This produces a hot, concentrated flame that can be directed at the specimen.

Charcoal block: Ideally, a small rectangular block of charcoal measuring approximately ½ x 1 x 4 inches. Such blocks can be purchased from mineral and chemical supply houses. A satisfactory substitute can be fashioned from the debris of almost any campfire, although such blocks are short lived and must be replaced regularly. In use, a small depression is made near one end of the block to hold the mineral charge, and the long end of the block is held away from the blowpipe flame. It is well to have long tweezers or pliers to hold the block, as it gets very hot in use.

Reagents

Ammonia (Ammonium hydroxide, NH_4OH): A dilute solution of ammonium hydroxide is used, made by adding one volume of concentrated ammonium hydroxide to two volumes of water.

Baking soda (Sodium bicarbonate, $NaHCO_3$): Although pure sodium carbonate (Na_2CO_3) is usually used in laboratories for this purpose, common household baking soda will serve.

Benzidine base: A solution of benzidine base and water can be used to identify bentonite. Unlike most reagents listed here, benzidine base is not readily obtainable and must be ordered from a chemical supply house if desired.

Cobalt nitrate, $Co(NO_3)_2$: The crystalline reagent is dissolved in ten parts of water for use. May not be available locally. Used only in tests for aluminum and zinc.

Dimethylglyoxime, $(CH_2)_2C_2(NOH)_2$: A fairly common organic reagent. A 2 percent solution in alcohol is used in the nickel test.

Hydrochloric acid (Muriatic acid, HCl): For use the concentrated acid may be diluted with an equal amount of water.

Nitric acid, HNO_3: Use the concentrated acid for silver test no. 2. For dilute acid, add one part of acid to two parts of water.

Sulfuric acid, H_2SO_4: Use the concentrated acid for the tellurium test. Concentrated sulfuric acid is a thick, somewhat oily liquid, and must be handled with care. If you desire to dilute the acid, for any reason, **add acid to water very slowly,** stirring the mixture constantly. The container will get hot, therefore it is best to use a pyrex container for this purpose. **Never add water to acid** as a violent and dangerous reaction will occur.

Von Kobell flux (KI plus S): Prepared by mixing equal parts of potassium iodide and sulfur.

CHEMICAL TESTS FOR ELEMENTS

Aluminum *(Al).*—Some of the infusible aluminum-bearing minerals (see bauxite and kaolinite) will turn blue if a small fragment is moistened with cobalt nitrate solution and then heated in the blowpipe flame. Bentonite will turn blue if a drop of benzidine base solution is placed on it. The intensity of the blue color is roughly proportional to the purity of the bentonite.

Bismuth *(Bi).*—A small quantity of the mineral suspected of containing bismuth is ground to a powder and mixed with three times it volume of baking soda. The mixture placed on the charcoal block and heated with the blowpipe flame will volatilize, producing on the charcoal a coating that is orange yellow near the sample and white farther away. Another test, if reagents are available, is to mix the sample with three times its volume of von Kobell's flux. This mixture, when heated by the tip of the blowpipe flame, will produce on the charcoal a yellow coating that is bright red along its outer margin.

Copper *(Cu).* Test 1—Most copper minerals when powdered and heated in dilute hydrochloric or nitric acid will turn the solution green. To confirm, add ammonia (ammonium hydroxide) in excess of the amount of acid; the solution will turn blue if copper is present (see also test for nickel, which reacts in a similar manner).

Test 2.—Hold a small fragment of the mineral in tweezers, moisten it with hydrochloric acid, and hold in the burner flame. Flame turns azure blue for copper. Works best on green copper minerals.

Nickel (Ni).—A powdered mineral containing nickel, when heated in dilute nitric acid, will turn the solution green (similar to copper but lighter in color). When ammonia is added in slight excess of the amount of acid used, the solution will turn blue (also lighter than in the similar copper reaction). To confirm the presence of nickel add a few drops of dimethylglyoxime solution, which will produce a bright red precipitate or band where the two solutions meet.

Silver (AG). Test 1.—Mix a small quantity of the powdered mineral with three times its volume of baking soda and fuse the mixture on charcoal with the blowpipe flame. A bright metallic bead of silver will be formed. If only a small amount of silver is present, it may be necessary to break up the resulting fusion to liberate the bead. The metallic bead will be bright and shiny even after cooling (see tin test).

Test 2.—Dissolve the powdered mineral (or the bead from test 1) in concentrated nitric acid. Then add a few drops of dilute hydrochloric acid or a few grains of table salt and a white precipitate will form. This precipitate, unlike other similar precipitates, will turn purple after a few minutes exposure to sunlight.

Tellurium (Te). Drop a few small grains of mineral into hot concentrated sulfuric acid. If they contain tellurium a reddish-violet plume will be observed coming from the mineral grains (see precautions in use of sulfuric acid under List of Reagents and Equipment).

Tin (Sn). The powdered mineral is mixed with an equal amount of powdered charcoal and two times its volume of baking soda. Moisten the mixture with water to make a paste, and heat on charcoal well back within the blowpipe flame. The reduction will produce one or more tiny beads of silvery metal. The bead(s) of tin, unlike those of silver (test 1) will become coated with a white powdery (oxide) coating upon cooling.

Zinc (Zn). Mix a small amount of the powdered mineral with one half its volume of baking soda. Make a paste of the mixture with water and take up the paste on a loop of fine iron wire (not galvanized). Make the loop about ⅛ inch in diameter. Moisten the charcoal block with cobalt nitrate and then hold the wire loop about one-half inch away from it. Heat the mineral mixture strongly well back within the blowpipe flame, directing the flame toward the moistened charcoal. If zinc is present, a green coating will form on the charcoal. Note: This test is sometimes difficult to perform. If the green coating forms, zinc has been proved, but failure to produce the coating cannot always be taken as proof of the absence of zinc.

To aid the reader in using the following tables a list of chemical elements and their symbols follows. This is an abbreviated list containing only the more common elements and those less common ones encountered in the mineral tables.

Finally, an outline of the mineral tables follows. To identify a mineral, the reader should first determine its luster, color, and hardness. Next, by consulting the outline, determine which table will contain the mineral to be identified. Then, after the correct table is selected, tests such as streak, physical properties, appearance, and simple chemical tests will allow precise identification of the mineral.

ELEMENTS AND SYMBOLS

Aluminum	Al	Gold	Au	Potassium	K
Antimony	Sb	Hydrogen	H	Selenium	Se
Arsenic	As	Iodine	I	Silicon	Si
Barium	Ba	Iron	Fe	Silver	Ag
Beryllium	Be	Lanthanum	La	Sodium	Na
Bismuth	Bi	Lead	Pb	Strontium	Sr
Cadmium	Cd	Lithium	Li	Sulfur	S
Calcium	Ca	Magnesium	Mg	Tantalum	Ta
Carbon	C	Manganese	Mn	Tellurium	Te
Cerium	Ce	Mercury	Hg	Thorium	Th
Chlorine	Cl	Molybdenum	Mo	Tin	Sn
Chromium	Cr	Nickel	Ni	Titanium	Ti
Cobalt	Co	Nitrogen	N	Tungsten	W
Columbium (Niobium)	Cb	Oxygen	O	Uranium	U
Copper	Cu	Phosphorus	P	Vanadium	V
Fluorine	F	Platinum	Pt	Zinc	Zn

OUTLINE OF MINERAL IDENTIFICATION TABLES

Luster	Color	Hardness	Table number
Minerals with metallic luster	Black or dark gray	Soft	1
		Medium	2
		Hard	3
	Silver or light gray	Soft	4
		Medium	None listed
		Hard	5
	Brass, bronze, copper, or other metallic	Soft	6
		Medium	7
		Hard	8
Minerals with nonmetallic luster	White or light gray	Soft	9
		Medium	10
		Hard	11
	Other colors	Soft	12
		Medium	13
		Hard	14

TABLE 3-1—MINERALS WITH METALLIC LUSTER
Color: Black or dark gray—soft

Mineral	Streak	Description and tests
Argentite Ag_2S	Dark gray	Color dark lead gray. Occurs as small grains (crystals) or filmlike veinlets. A common primary silver mineral. Sectile. Test 1 for silver.
Chalcocite Cu_2S	Dark gray black	Color shiny dark gray or dull black. Occurs massive or as granular aggregates, occasionally in distinct crystals. Soft, somewhat sectile. Reduce to copper globule on charcoal B.B.
Graphite C	Black	Color black to dark gray. Occurs as flaky or scaly masses, sometimes massive. Very soft, will soil fingers (black). Brownish between flakes (see molybdenite). Streak and softness are distinctive, also has a greasy feel.
Jamesonite $2PbS.Sb_2S_3$	Grayish black	Color steel gray to dark gray. Occurs as long, thin radiating or fibrous crystals, sometimes matted or felty. Usually small. Thin wirelike or needlelike crystals distinctive. Fusible.
Polybasite $9Ag_2S.Sb_2S_3$	Black	Color metallic black. Occurs as small tabular crystals. Test 2 for silver. B.B. fuses with spurting to globule.
Pyrargyrite (Ruby silver) $3Ag_2S.Sb_2S_3$	Purple-red	Color black to gray black, shiny. Occurs as bands or veins, less commonly as distinct crystals. Gives a deep-red powder when scratched. May look dark red on rough surfaces. Streak and color of powder are distinctive. Test 2 for silver.
Pyrolusite MnO_2	Black	Color black to steel gray. Occurs as thin needlelike and columnar crystal aggregates, sometimes massive. Very soft, will soil fingers. Softness, streak, and form are distinctive. Gives off chlorine gas when dissolved in hydrochloric acid.

TABLE 3-2—MINERALS WITH METALLIC LUSTER
Color: Black or dark gray—medium hard

Mineral	Streak	Description and tests
Enargite Cu_3AsS_4	Gray black	Color black to gray black. Occurs as small striated prismatic crystals with lens-shaped cross section; sometimes massive or granular. Easily scratched with knife. Cleavable (breaks along smooth flat surfaces).
Tennantite $3Cu_2S.As_2S_3$	Dark gray	Color dark gray to black. Occurs as massive or granular aggregates, when crystallized, as small 4-sided crystals. Crystal faces and fracture surfaces very shiny. Easily scratched with knife but not cleavable.
Tenorite CuO	Black	Black copper oxide. Occurs as black scales on the surfaces of other copper minerals. Also, occasionally massive or earthy. Frequently contains iron and sometimes known as "copper pitch". Gives metallic copper globule on charcoal when heated B.B., or Test 2 for copper.
Tetrahedrite $3Cu_2S.Sb_2S_3$	Black	Color dark gray to black, shiny, similar to tennantite. Occurs commonly in crystals with triangular faces, also massive. Silver-bearing variety is called freibergite and has reddish streak. Easily fusible. Crystal form is distinctive.
Wolframite $(FeMn)WO_4$	Black	Black to dark gray or brown. Occurs as tabular or bladed crystals. Hard, scratched with difficulty by pocket knife. Manganese variety is called huebnerite. Easily fusible. Hardness somewhat distinctive. Chemical test for W.

TABLE 3-3—MINERALS WITH METALLIC LUSTER
Color: Black or dark gray—hard.

Mineral	Streak	Description and tests
Chromite $FeCr_2O_4$	Brown	Color black to slightly brownish black. Occurs as granular aggregates, sometimes as distinct 8-sided crystals. Like magnetite, but nonmagnetic. Hardness and streak are fairly distinctive. Essentially infusible.
Columbite-tantalite $(FeMn)(NbTa)_2O_{16}$	Dark red to black	Color black to gray black. Occurs as short tabular crystals. Columbite and tantalite are related minerals containing columbium (niobium) and tantalum respectively. Infusible. Streak fairly distinctive. X-ray test for Cb and Ta.
Ilmenite $FeTiO_3$	Black to brown red	Color black to iron gray. Usually occurs massive or in granular aggregates, occasionally in crystals. Usually associated with magnetite, but not attracted to the magnet itself. Infusible, hard, nonmagnetic. Chemical test for Ti.
Magnetite Fe_3O_4 lodestone	Black	Color black, commonly occurs as massive or granular aggregates. Crystals small, 8 or 12 sided. Heavy. Attracted to a magnet. Difficult to fuse. Magnetic.
Psilomelane MnO_2+ other oxides	Brown black	Color iron black with dull metallic luster. Usually massive. Evolves chlorine fumes in hydrochloric acid. (See pyrolusite, table 1). Noncrystalline. Infusible.

TABLE 3-4—MINERALS WITH METALLIC LUSTER
Color: Silver or light gray—Soft

Mineral	Streak	Description and tests
Bismuthinite Bi_2S_3	Gray	Color lead gray. Usually massive, sometimes in fibrous crystals. Very soft. Sectile. Chemical test for Bi. Fusible.
Calaverite $AuTe_2$	Gray	Color silver white. Occurs as small needlelike crystals, occasionally massive to granular. A grain of a telluride dropped into fuming sulfuric acid will give a distinctive red-purple plume (see test for tellurium). Fusible. When heated strongly on charcoal with sodium carbonate will give gold bead.
Galena PbS	Lead gray	Color silver gray, shiny. Usually well crystallized, less commonly fine granular, almost massive. Cleavage is very distinctive. Perfect cleavage, breaks to form cubic or square fragments. Fusible.
Mercury Hg	None	Color silver. The only element that occurs as a liquid at normal temperatures. Easily recognized. Liquid. Completely volatile when heated, forms poisonous fumes.
Molybdenite MoS_2	Greenish gray	Color silver to light gray. Occurs in thin flexible plates, occasionally fine granular to massive. Very soft, will mark fingers silver gray. (Bluish between flakes.) Sectile. Streak and softness are distinctive.
Silver Ag	Silver gray	Color silver gray, tends to tarnish darker on exposure. Very soft and sectile. Occurs as wirelike filaments, occasionally massive. Test 2 for silver.
Stibnite Sb_2S_3	Lead gray	Color shiny lead gray, sometimes tarnished black. Occurs as elongate radiating crystals. Easily fusible in flame of match. Slightly sectile. Turns flame blue green.
Sylvanite $(AuAg)Te_2$	Gray	Color silver white. Usually occurs as small bladed crystals or branching filaments. Usually very small. Test for tellurium (see calaverite), also test 2 for silver.

TABLE 3-5—MINERALS WITH METALLIC LUSTER
Color: Silver or light gray—hard.

Mineral	Streak	Description and tests
Arsenopyrite $FeAsS$	Black	Color silver white. Commonly occurs as elongate and triangular crystals. Streak and hardness are distinctive. Evolves arsenic fumes when heated (smell like garlic).
Specularite Fe_2O_3	Brick red	Color silver, sometimes with reddish cast. Also called specular hematite. Occurs as granular, laminated, or foliated masses. Streak is diagnostic.

TABLE 3-6—MINERALS WITH METALLIC LUSTER
Color: Brass, bronze, copper, or other metallic—soft.

Mineral	Streak	Description and tests
Bornite Cu_5FeS_4	Gray black	Color reddish to purplish bronze on fresh surfaces and scratches, tarnished to bright blue on older surfaces. Usually massive but occasionally occurs as cubic crystals. Fusible. Bronze color on fresh breaks is diagnostic.
Copper Cu	Copper red	Copper colored, sometimes tarnished nearly black on weathered surfaces. Usually massive or wirelike, occasionally in small cubic or 8-sided crystals. Recognized by color, softness, malleability. Copper wetted with acid and held in a flame will turn flame blue.
Covellite CuS	Gray black	Color indigo blue like bornite, but does not change color on fresh breaks and scratches. Commonly occurs as massive or fine-granular aggregates, occasionally as tabular crystals. Very soft, associated with other copper sulfides. Blue covellite turns bright purple when wetted. Fusible. When dipped in hydrochloric acid and held in flame turns flame blue.
Gold Au	Gold yellow	Color gold yellow. Occurs as irregularly shaped masses and specks. In placer deposits sometimes flat flakes. Very soft, malleable, and sectile. Hardness, color, and streak are diagnostic.

TABLE 3-7—MINERALS WITH METALLIC LUSTER
Color: Brass, bronze, copper, or other metallic—medium hard.

Mineral	Streak	Description and tests
Chalcopyrite $CuFeS_2$	Green black	Color brass yellow, sometimes tarnished darker. Usually occurs as irregular masses, less commonly granular and crystalline. Scratched with a knife, but gives powder-like streak. Distinguished from gold and pyrite by streak-color and hardness.
Niccolite $NiAs$	Brown black	Color silver with a pinkish cast. Generally massive. Scratched only with difficulty. Color distinctive. Chemical test for nickel.
Pentlandite $(FeNi)S$	Brown	Color light bronze. Occurs as compact, granular masses. Easily scratched with knife. Nonmagnetic (see pyrrhotite). Streak, color, and nonmagnetic character is diagnostic. Chemical test for Ni.
Pyrrhotite FeS approx.	Gray black	Color light bronze. Occurs as compact granular masses. Easily scratched with knife. Magnetic (attracted to magnet). Often associated with pentlandite (test for Ni). Streak and magnetic property are diagnostic.

TABLE 3-8—MINERALS WITH METALLIC LUSTER
Color: Brass, bronze, copper, or other metallic—hard.

Mineral	Streak	Description and tests
Marcasite FeS_2	Gray black	Color very pale yellow. Usually a secondary mineral, occurs as tabular crystals or masses. Not scratched by knife. Also called white iron pyrite. Distinguished from pyrite by lighter color.
Pyrite FeS_2	Black	Color pale brass yellow. Commonly occurs as cube crystals. Also as 8- and 12-sided crystals, sometimes massive. Hardness, color, and streak serve to distinguish from similar minerals.

TABLE 3-9—MINERALS WITH NONMETALLIC LUSTER
Color: White or light gray—soft.

Mineral	Streak	Description and tests
Anglesite $PbSO_4$	White	Color usually white to light gray, occasionally pale green or yellow. Commonly occurs as fine granular masses, rarely as tabular or pyramidal crystals. A secondary mineral from alteration of lead sulfide. Very heavy and soft. Heated on charcoal with baking soda B.B. will reduce to metallic lead.
Asbestos	White	Color occasionally pale gray, more commonly green to gray green. Occurs as fiberous or felty masses. Very soft, with a soapy feel. Easily scratched with finger nail.
Bauxite $Al_2O_3.2H_2O$	Variable white, yellow, brown	Color occasionally white to gray, more commonly reddish to yellowish brown, dependent upon impurities. Occurs as rounded (pisolitic and oolitic) grains, also as fine-grained earthy masses. Heated with cobalt nitrate, turns blue **without** fusion.
Bentonite (Montmorillonite)		Color white to gray, pink, green, blue or brown; more commonly buff to yellow. Occurs as fine-grained masses. A clay mineral with a clayey feel and odor when moist. Surface exposures, when dry, resemble pop corn; when wet, slick soft soap. Most varieties swell in water. When moistened with water solution of benzidine base, turns blue.
Cerargyrite AgCl	White to gray	Color white, gray, greenish or brownish gray, waxy, also called "horn silver". Occurs as an encrusting to massive alteration of silver minerals. Very soft and sectile. Resembles dirty candle grease. Use test 1 for silver.
Gypsum $CaSO_4$	White	Colorless to white, sometimes gray to greenish gray. Tabular colorless crystals break (cleave) along smooth planes. Very soft, scratched easily with fingernail. Also occurs as fine-grained masses. Form and softness usual criteria. Also chemical and optical tests. Can be chewed without grittiness if pure.
Kaolinite $Al_2Si_20_7.2H_2O$	White	Color white when pure, more commonly buff to yellow. Occurs as fine-grained earthy masses. Has a clayey feel and odor when moist. A clay mineral. Heated with cobalt nitrate turns blue.
Muscovite (white mica)	White	Color gray to greenish gray, less commonly white. Occurs as flat elastic plates that are easily separated. A mica mineral. Soft, easily scratched. Form and color usually distinctive.
Talc $H_2Mg_3(SiO3)4$	White	Color pale greenish gray, less commonly dark green, gray white, and white. Occurs as fine-grained foliated masses, less commonly massive. Very soft, sectile, has a scapy feel. Softness, soapy feel, and form usually distinctive.

TABLE 3-10—MINERALS WITH NONMETALLIC LUSTER
Color: White or light gray—medium hard.

Mineral	Streak	Description and tests
Aragonite $CaCO_3$	White	Color usually white to light yellow, occasionally gray, green, or violet. Occurs as encrusting crystals around hot springs and as stalactites in caves. Sometimes massive. Easily scratched with knife. Effervesces (bubbles) in dilute hydrochloric acid.
Barite $BaSO_4$	White	Color usually white to buff, less commonly yellow, brown, and reddish. Occurs both in beds (sedimentary) and in veins. May be massive or encrusting. Heavy, has prominent cleavage (breaks along smooth planes). Expands and 'pops' when small fragment is heated B.B. Turns flame yellow green when moistened with HC1.
Calcite $CaCo_3$	White	Usually white to gray white or colorless, occasionally yellow, blue, or green. Occurs fine grained (limestone), coarse grained (marble), or very coarse in veins, etc. Very prominent cleavage (breaks along smooth planes) to form rhombic fragments. Easily scratched by knife. Effervesces (bubbles) in dilute hydrochloric acid.
Cerussite $PbCO_3$	White to light gray	Color white to gray. Usually massive, granular, earthy, sometimes as incrusting tabular crystals. Very heavy. Often has a greasy appearance. Recognize by weight, does not expand B.B. (see barite). Reduces to metallic lead on charcoal B.B.
Dolomite $(CaMg)CO_3$	White to light gray	Usually white to gray, sometimes flesh color, buff, or black (impure). Occurs massive and granular in sedimentary beds, and as well-formed crystals in vein deposits. Has rhombic cleavage like calcite. Similar to calcite but slightly harder. Usually will not effervesce in hydrochloric acid unless powdered or heated.
Fluorite CaF_2	White	Color usually apple green to blue green, also violet, and sometimes colorless, white, or gray. Occurs as cubic crystals, also massive. Very prominent cleavage, breaks along smooth planes in four directions (perfect octahedral). Does not effervesce in hydrochloric acid (see calcite and dolomite). When dissolved in sulfuric acid the solution will etch glass.
Hemimorphite (Calamine) $H_2Zn_2SiO_5$	White	Color usually white, also gray, pale green, or pale blue. Usually occurs as fibrous crystals, also massive and granular. Infusible. Test for zinc. Gels in hot hydrochloric acid.
Scheelite $CaWO_4$	White	Color white to yellow brown. Occurs as pyramidal crystals, as small disseminated grains in veins, and as fine granular masses. Very heavy. Fluoresces under short-wave ultra-violet light (blue white if pure, apple green to yellow if Mo present). Where molybdenum predominates over tungsten, the mineral is called powellite.

TABLE 3-11—MINERALS WITH NONMETALLIC LUSTER
Color: White or light gray—hard.

Mineral	Streak	Description and tests
Amphibole	Gray green, gray brown, or yellow	Amphibole is actually a name that identifies a group of minerals, the most common of which is hornblende. Color black to greenish black, occasionally brown. Occurs as elongate crystals with well-developed crystal faces. Common in igneous and metamorphic rocks. Some metamorphic varieties white to light gray. Crystal faces make angles of 60° and 120° with each other. Form is distinctive.
Beryl $Be_3Al_2(SiO_3)_6$	White	Colors: colorless, white (common), green (emerald), rose (morganite), blue (aquamarine). In elongate 6-sided crystals, also granular aggregates. Often resembles quartz but is harder. Will scratch glass.
Cassiterite SnO_2	Yellow brown	Color usually brown to red brown, occasionally white to gray white. Very hard and heavy, usually found in placer deposits as small rounded brown pebbles. When crystalline usually as radiating. Weight, color, and streak usually sufficient. Confirm by chemical test for tin.
Chalcedony SiO_2	White	Colors white to light gray, also red, brown, yellow. Chalcedony is actually a very fine grained form of quartz. Hard, light, and breaks with a smooth curved surface like glass. Waxy luster or appearance. Hardness, luster, and fracture are distinctive.
Corundum Al_2O_3	White	Color usually gray to gray green, sometimes white, red (ruby), or blue (sapphire). Usually occurs as elongate 6-sided crystals, in placers as rounded pebbles. Very hard, will scratch all natural substances except diamond. Hardness is diagnostic.
Orthoclase $KAlSi_3O_8$	White	As used here includes microcline and orthoclase, or potash feldspar. Color commonly white, also pale gray, buff, pink, and occasionally green. Usually occurs as well-developed blocky crystals. Luster shiny, pearly, earthy when weathered, breaks along smooth plane surfaces (cleaves). Form, luster, and cleavage usually are sufficient. Lacks multiple twinning, see plagioclase.
Plagioclase $(NaCa)Al_2Si_2O_8$	White	Includes the various sodium-calcium feldspars. Color usually white to gray, occasionally brown or blue. Usually occurs as well-developed blocky crystals. Luster and cleavage like orthoclase. Distinguished from orthoclase by presence of multiple twinning, which produces finely striated surfaces on crystals. Striations due to twinning are distinctive.
Quartz SiO_2	White	Colorless, white, gray, less commonly brown, violet (amethyst), green, pink, red. Commonly occurs as well developed 6-sided crystals, also massive, granular and microcrystalline (chalcedony). Breaks with smooth curved surfaces. Hard. Form and character of broken surfaces are good criteria.
Smithsonite $ZnCO_3$	White to gray	Color green, gray green, sometimes gray to gray white. Usually granular to massive, encrusting, sometimes as stalactites. Powdered mineral will effervesce (bubble) in dilute hydrochloric acid. Infusible. Test for zinc.

TABLE 3-12—MINERALS WITH NONMETALLIC LUSTER
Colors: Other than white or light gray—soft.

Mineral	Streak	Description and tests
Anglesite $PbSO_4$	White	Color usually white to light gray, occasionally pale green or yellow. Commonly occurs as fine granular masses, rarely as tabular or pyramidal crystals. A secondary mineral from alteration of lead sulfides. Very heavy and soft. Heated on charcoal with baking soda B.B. will reduce to metallic lead.
Asbestos	White	Color occasionally light gray, more commonly green to gray green. Occurs as fibrous or felty masses. Very soft with a soapy feel. Easily scratched by a fingernail.
Autunite $Ca(UO_2)_2.P_2O_5.8H_2O$	Yellow	Color sulfur yellow. Occurs as thin rectangular flakes, occasionally in tabular crystals. Usually encrusting or in minute veins in fractures. An alteration product of primary uranium minerals. Radioactive. Fluoresces apple green under ultra-violet light.
Bauxite $Al_2O_3.2H_2O$	Variable white, yellow, brown	Color occasionally white to gray, more commonly reddish to yellowish brown, dependent upon impurities. Occurs as rounded (pisolitic or oolitic) grains, also as fine-grained earthy masses. Heated with cobalt nitrate, it turns blue without fusion.
Bentonite (Montmorillonite)	Variable	Color occasionally white to gray, pink, green, blue, or brown; more commonly buff or yellow. Occurs as fine-grained masses. A clay mineral with a clayey feel and odor when moist. Most varieties swell in water. When moistened with water solution of benzidine base, turns blue.
Biotite	Grayish white	Color black to dark brown, occasionally deep green. Occurs as flat elastic plates that are easily separated. A mica mineral. Soft, easily scratched. Form and color are distinctive.
Bornite Cu_5FeS_4	Gray black	Color reddish to purplish bronze on fresh surfaces and scratches, tarnished to bright blue on older surfaces. Usually massive, but occasionally occurs as cubic crystals. Fusible. Bronze color on fresh surfaces is diagnostic.
Carnotite $K_2O.2U_2O.V_2O_5.3H_2O$	Yellow	Color canary yellow. Occurs as powdery or earthy films or masses, often as cementing material between sand grains, occasionally as larger folia or plates. The most common secondary uranium mineral. Radioactive. Color distinctive. Does not fluoresce under ultra-violet light.
Chalcanthite $CuSO_4.5H_2O$	White to blue white	Color bright blue on fresh surfaces, powdery blue to pale blue green on weathered surfaces. Occurs as an encrusting precipitate, usually from copper-rich mine waters. Color and very bitter taste are diagnostic.
Chlorite	White to greenish	Color dark green to greenish black. Occurs as a rock constituent mineral or in platy masses. Characterized by a mica-like platy cleavage. Soft. Color and softness distinctive.
Chrysocolla $CuSiO_3.2H_2O$	White, greenish white, blue white	Color green to blue green. Occurs as fine-grained crusts or seam fillings. Soft, with a shiny to earthy luster. Swells and pops in blowpipe flame. Test 2 for copper.
Cinnabar HgS	Scarlet	Color red to brownish red, occasionally almost black. Sometimes occurs as tabular crystals, more commonly as fine-grained masses or disseminated. Luster shiny when crystalline, dull when earthy. Somewhat sectile. Streak and color distinctive. Completely volatile in flame B.B. (gives off poisonous fumes).

TABLE 3-12—*(continued)*

Mineral	Streak	Description and tests
Coal	Brown to black	Color black, some low-grade varieties (lignite) brown. Occurs in beds and seams. Very light. Luster may be shiny or dull. Recognized by its light weight. Test by combustion.
Covellite CuS	Gray black	Color indigo blue, like bornite, but does not change color on fresh breaks and scratches. Commonly occurs as massive or fine granular aggregates, occasionally as tabular crystals. Very soft, associated with other copper sulfides. Blue covellite turns bright purple when wetted. Fusible. When dipped in hydrochloric acid and held in flame, will turn flame blue.
Kaolinite $Al_2Si_2O_7.2H_2O$	White	Color white when pure, more commonly buff to yellow. Occurs as fine-grained earthy masses. Has a clayey feel and odor when moist. A clay mineral. Heated with cobalt nitrate, it turns blue.
Lepidolite	White	Color lavender to pale violet. Occurs in plates and flakes essentially restricted to pegmatite deposits. A mica mineral, distinguished from other micas by color. Mica cleavage and lavender color are distinctive.
Muscovite (White mica)	White	Color gray to greenish gray, less commonly white. Occurs as flat elastic plates that are easily separated. A mica mineral. Soft, easily scratched. Form and color are usually distinctive.
Orpiment As_2S_3	Yellow	Color lemon yellow. Sectile. Occurs as foliated masses associated with other arsenic minerals or metal arsenides. Usually with realgar (see below). Color and streak are distinctive. B.B. burns with blue flame and gives off garlic odor.
Proustite (Ruby silver) $3Ag_2S.As_2S_3$	Red	Color vermillion red. Occurs as small crystals or fine-grained masses in veinlets. Soft and brittle. Test 2 for silver. Distinguished from cinnabar by somewhat different color and streak.
Realgar AsS	Orange red	Color red to orange red, like streak. Occurs massive or fine granular, usually with orpiment (see above). Associated with other arsenic minerals or metal arsenides. Sectile. Color and softness are distinctive.
Serpentine $H_4Mg_3Si_2O_9$	White	Color gray green to green. Occurs massive. A form of asbestos. Soft, easily scratched. Has a soapy feel. Form, softness, soapy feel are distinctive.
Talc $H_2Mg_3(SiO_3)_4$	White	Color pale greenish gray, less commonly dark green, gray white, and white. Occurs as fine-grained and foliated masses, less commonly massive. Very soft, sectile, has a soapy feel. Softness, soapy feel, and form usually distinctive.
Torbornite $Cu(UO_2)_2.P_2O_5.12H_2O$	Pale apple green	Color apple green to emerald green. Occurs as foliated crusts. Occasionally as well-developed square tabular crystals. Soft. Radioactive. Color is distinctive. Not fluorescent under ultra-violet light.
Wulfenite $PbMoO_4$	White	Color waxy orange to yellow, rarely green to white. Usually occurs as square tabular crystals associated with primary lead or molybdenum minerals. Swells and pops B.B. Fused with baking soda on charcoal yields metallic lead.

TABLE 3-13—MINERALS WITH NONMETALLIC LUSTER
Colors: Other than white or light gray—medium hard.

Mineral	Streak	Description and tests
Aragonite $CaCO_3$	White	Color usually white to light yellow, occasionally gray, green, or violet. Occurs as encrusting crystals around hot springs and as stalactites in caves. Sometimes massive. Easily scratched with a knife. Effervesces (bubbles) in dilute hydrochloric acid.
Azurite $2CuCO_3.Cu(OH)_2$	Blue	Color deep blue when crystalline, pale blue to blue white when weathered or earthy. Usually as earthy masses, less commonly as bright-blue encrusting crystals. Usually associated with (green) malachite. Effervesces (bubbles) in dilute nitric acid. Test 2 for copper.
Barite $BaSO_4$	White	Color usually white to buff, less commonly yellow, brown, and reddish. Occurs both in beds (sedimentary) and in veins. May be massive or encrusting. Heavy, has prominent cleavage (breaks along smooth planes). Expands and "pops" when small fragment is heated B.B. Turns flame yellow green when moistened with hydrochloric acid.
Bismutite $Bi_2O_3.CO_2.H_2O$	White	Color may be white, yellow, green, or gray. Occurs as an encrusting or earthy mass. A secondary mineral usually associated with primary bismuth ores. Fusible. Effervesces (bubbles) in dilute hydrochloric acid. Test for Bi.
Calcite $CaCO_3$	White	Usually white to gray white or colorless, occasionally yellow, blue, or green. Occurs fine grained (limestone), coarse grained (marble), or very coarse in veins, etc. Very prominent cleavage (breaks along smooth planes) to form rhombic fragments. Easily scratched by knife. Effervesces (bubbles) in dilute hydrochloric acid.
Cuprite CuO	Brown red	Color bright red to dark red. Occasionally in bright colored crystals, more commonly as earthy masses. An oxidation product of primary copper minerals. Color and streak are distinctive. Moistened with hydrochloric acid and placed B.B. will turn flame blue.
Dolomite $(CaMg)CO_3$	White to light gray	Usually white to light gray, sometimes flesh color, buff, or black (impure). Occurs massive or granular in sedimentary beds, and as well-formed crystals in vein deposits. Has rhombic cleavage like calcite. Similar to calcite, but slightly harder. Usually will not effervesce in hydrochloric acid unless powdered or heated.
Fluorite CaF_2	White	Color usually apple green to blue green, also violet and sometimes colorless, white, or gray. Occurs as cubic crystals, also massive. Very prominent cleavage, breaks along smooth planes, in four directions (perfect octahedral). Does not effervesce in hydrochloric acid (see calcite and dolomite). When dissolved in sulfuric acid the solution will etch glass.
Goethite $Fe_2O_3.H_2O$	Yellow brown	Color reddish to blackish brown. Usually in long thin radiating or fibrous crystals forming rounded masses. An oxidation product of iron sulfides. Distinguished from other red oxides by yellow-brown streak. Heavier than limonite (Sp. gr. 4.4).
Hemimorphite (Calamine) $H_2Zn_2SiO_5$	White	Color usually white, also gray, pale green, or pale blue. Usually occurs as fibrous crystals, also massive and granular. Infusible. Test for zinc. Gels in hot hydrochloric acid.
Limonite $Fe_2O_3.nH_2O$	Yellow brown	Color yellow brown to yellow ocher. Usually occurs as granular earthy masses. Sometimes occurs as pseudomorphs after pyrite. Yellow-brown streak. Difficult to distinguish from goethite, but is lighter (Sp. gr. 3.6-4.0).
Malachite $CuCO_3.Cu(OH)_2$	Pale green	Color bright green. Occurs as earthy masses or as bright green, elongate, radiating crystals. When crystalline has a silky luster. Often with azurite. Effervesces in dilute hydrochloric acid. Test 2 for copper.

TABLE 3-13—(continued)

Mineral	Streak	Description and tests
Monazite $(CeLa)PO_4+ThSiO_4$	White	Color brown to red brown, occasionally yellow brown. Occurs as tabular crystals when found in primary deposits. Usually in placer accumulations. Very heavy. Radioactive (contains thorium).
Rhodochrosite $MnCO_3$	White	Color rose, yellow gray, buff. Occurs as granular or encrusting masses. More rarely as crystals. Frequently with black manganese oxide stain on surface. Will effervesce in warm hydrochloric acid (bubbles).
Scheelite $CaWO_4$	White	Color white to yellow brown. Occurs as pyramidal crystals, as small disseminated grains in veins, and as fine granular masses. Very heavy. Fluoresces under ultra-violet light (blue white if pure, apple green to yellow if Mo is present). Where molybdenum predominates over tungsten, the mineral is called powellite.
Siderite $FeCO_3$	White	Color yellow brown to red brown, also yellow gray. Occurs as rhombohedral crystals, also massive and granular. A common gangue mineral associated with iron oxides. Effervesces in dilute hydrochloric acid.
Sphalerite ZnS	White	Color yellow, yellow brown, dark brown, and dark greenish gray. Occurs as fine- to coarse-grained aggregates in veins and lodes with other sulfides. Has prominent cleavage (breaks along smooth planes). Gives off sulfurous fumes in hydrochloric acid.
Titanite $CaTiSiO_5$	White	Color brown, yellow gray, occasionally green, red, black. Occurs as wedge-shaped crystals. Hard, scratched only with difficulty. Also known as sphene. Shape and hardness distinctive.
Uraninite $UO_2.UO_3$	Gray black to brown black	Color gray black, greenish black, brownish black, black. Usually massive, sometimes in small 8-sided crystals. Hard. Scratched only with difficulty. Radioactive. Not fluorescent in ultra-violet light.
Wolframite $(Fe,Mn)WO_4$	Black	Black to dark gray or brown. Occurs as tabular or bladed crystals. Hard, scratched with difficulty by pocket knife. Manganese variety is called huebnerite. Easily fusible. Hardness somewhat distinctive. Chemical test for W.

TABLE 3-14—MINERALS WITH NONMETALLIC LUSTER
Colors: Other than white or light gray—hard.

Mineral	Streak	Description and tests
Amethyst SiO_2	White	Color purple. Commonly occurs as well-developed 6-sided crystals, pointed on one end lining the walls of vugs or openings in the rocks. Amethyst is a variety of quartz. Hard. Breaks along smooth curved surfaces.
Amphibole	Gray green, gray brown, or yellow	Amphibole is actually a name that identifies a group of minerals, the most common of which is hornblende. Color black to greenish black, occasionally brown. Occurs as well-developed crystals with elongate form. Common in igneous and metamorphic rocks. Some metamorphic varieties white to light gray. Crystal faces make angles of 60° to 120° with each other. Form is fairly distinctive.
Beryl $Be_3Al_2(SiO_3)_6$	White	Colorless, white (common), green (emerald), rose (morganite), blue (aquamarine). In elongate 6-sided crystals, also granular aggregates. Often resembles quartz, but is harder. Will scratch glass.
Cassiterite SnO_2	Yellow brown	Color usually brown to red brown, occasionally white to gray white. Very hard and heavy, usually found in placer deposits as small rounded brown pebbles. When crystalline, usually as radiating, fibrous crystals. Weight, color, and streak usually sufficient. Confirm by chemical test for tin.

TABLE 3-14—(continued

Mineral	Streak	Description and tests
Chalcedony SiO_2	White	Colors white to light gray, also red, brown, yellow. Chalcedony is actually a very fine-grained form of quartz. Hard, light, and breaks with a smooth curved surface like glass. Waxy luster or appearance. Hardness, luster, and fracture are distinctive.
Corundum Ai_2O_3	White	Color usually gray to gray green, sometimes white, red (ruby), and blue (sapphire). Usually occurs as elongate 6-sided crystals; in placers as rounded pebbles. Very hard, will scratch all natural substances except diamond. Hardness is diagnostic.
Epidote	White to gray white	Color yellow green, green, or yellow (more commonly green). Occurs as elongate, radiating striated crystals. Usually a metamorphic mineral found in contact zones. Fuses and swells to form a black slag when a small fragment is heated B.B.
Garnet	White	Color red, red brown, brown, occasionally almost black, green. Occurs as small equidimensional crystals appearing much like glass beads. Also massive. Garnet is a term that identifies several similar (garnet group) minerals. Distinguished by color, shape, and hardness.
Hematite Fe_2O_3	Brick red	Color brick red to red brown. Occurs as earthy masses, as oolitic masses, occasionally as foliated crystals (see specularite). When earthy, appears softer. Streak is distinctive.
Jadeite	White	Color apple green, dark green, greenish white. Occurs as massive or fine granular aggregates. A form of jade. Fuses to a bubbly glass B.B. Turns flame yellow.
Olivine $(MgFe)_2SiO_4$	White to yellow white	Color green, olive green, forest green. Occurs as small well-formed crystals in basic igneous rocks. Color and association distinctive.
Orthoclase $KAlSi_3O_8$	White	As used here includes microcline and orthoclase, or potash feldspar. Color commonly white, also pale gray, buff, pink, and occasionally green. Usually occurs as well-developed, blocky crystals. Luster shiny, pearly, earthy when weathered. Breaks along smooth planes (cleavage). Form, luster, and cleavage usually are sufficient. Lacks multiple twinning, see plagioclase.
Plagioclase $(NaCa)Al_2Si_2O_8$	White	Includes the various sodium-calcium feldspars. Color usually white to gray, occasionally brown or blue. Usually occurs as well-developed blocky crystals. Luster and cleavage like orthoclase. Distinguished from orthoclase by multiple twinning, which produces finely striated surfaces on crystals. Striations due to twinning are distinctive.
Pyroxene	White to gray green	Color black to greenish black, some varieties grayish to brownish. Occurs as stubby well-formed crystals in igneous and metamorphic rocks. Shiny luster, somewhat dulled by weathering. A name that applies to a group of similar minerals. Tends to break (cleave) to make angles of 90° between faces. Fuses to black or green-black glass B.B.
Quartz SiO_2	White	Colors: colorless, white, gray, less commonly brown, violet (amethyst), green, pink, red. Commonly occurs as well-formed 6-sided crystals, also massive, granular, and microcrystalline (chalcedony). Breaks with smooth curved surfaces. Hard. Form and character of broken surfaces are good criteria.
Rhodonite $MnSiO_3$	White	Color pink, flesh colored, buff. Commonly occurs as massive or granular aggregates, occasionally as tabular crystals. Associated with black manganese oxides. Color and hardness are distinctive.
Smithsonite $ZnCO_3$	White to gray	Color green to gray green, sometimes gray to gray white. Usually granular to massive, encrusting, sometimes as stalactites. Powdered mineral will effervesce (bubble) in dilute hydrochloric acid. Infusible. Test for zinc.

TABLE 3-14—(*continued*)

Mineral	Streak	Description and tests
Staurolite $HFeAl_2Si_2O_{13}$	White to gray	Color red brown, dark brown, or yellow brown. Occurs as well-developed 6-sided crystals, frequently penetrating each other to form crosses. A metamorphic mineral. Infusible B.B. Hard, will scratch glass.
Topaz $(AlF)_2SiO_4$	White	Color pale yellow, rarely gray, blue, green, or red. Occurs as small well-formed 8- and 10-sided crystals. Shiny luster. Has one perfect cleavage, breaks on a smooth plane surface at right angles to crystal length. Very hard, will scratch glass.
Tourmaline	White	Color black, less commonly pink, green, blue, lavender (gem varieties). Gem varieties often bicolored. Occurs as well-developed elongate crystals with triangular, 6-sided, or rounded cross section, commonly in radiating groups. Common in veins and in pegmatites. Crystals are striated longitudinally. Color, shape, and striations are distinctive.

INSTRUCTIONS FOR USING ROCK IDENTIFICATION TABLES

The rock identification tables, like those for mineral identification, have been designed to allow rough rock identification by a process of progressive reduction into groups. As there are far fewer rock types to be considered, each of the major rock groups is presented in a separate table.

The first breakdown separates rocks into igneous, sedimentary, and metamorphic groups. Although this first separation is usually easy, there are rocks that make it difficult.

Igneous rocks are those that are believed to have formed from the solidification of once-molten rock (magma). These include such common intrusive rocks as granite and granodiorite, found in and near many mining districts, and also the fine-grained extrusive rocks formed in lava flows and as dikes and sills.

Sedimentary rocks can be subdivided into two subgroups: clastic sediments and chemical precipitates. The clastic sedimentary rocks include such common examples as sandstone and shale. They represent the accumulation of mineral and rock fragments derived from the erosion of older rocks and cemented together (lithified) to form solid rock. Chemical sediments include rocks formed as a precipitate from solutions (especially sea water).

Metamorphic rocks may have been either igneous or sedimentary originally, but they have undergone important changes since formation. These changes may result from high temperature, high pressure, or a combination of both. Slight metamorphism usually causes only slight hardening and compaction of the rocks. With more strenuous metamorphism, the rocks may develop lineation (all elongate crystals turned parallel to each other), foliation (platy or planar structure), or new metamorphic minerals in the rock (e.g., garnet, corundum, staurolite).

After a given rock is classified as igneous, sedimentary, or metamorphic, individual species can be recognized (by use of the tables) on the basis of the minerals present in the rock, grain size, and other physical characteristics.

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TABLE 3-15—TABLE OF IGNEOUS ROCKS

	Orthoclase predominant feldspar		Plagioclase predominant feldspar			
	No quartz	**Quartz**	**Quartz**	**Little or no quartz**	**No quartz**	**Olivine, no quartz**
	Dark minerals, if present, usually amphibole or biotite or muscovite.		Feldspars white to light gray. Dark minerals usually amphibole or biotite.		Feldspars gray. Dark minerals usually pyroxene and sometimes biotite.	
	Usually light colored.		**Usually medium colored.**		**Usually dark colored.**	
Coarse to medium grained. Individual mineral grains are easily discernible.	Syenite	Granite	Granodiorite	Diorite	Gabbro	Olivene gabbro
Medium-grained porphyry. Mass of the rock is medium grained but contains numerous much larger crystals.	Porphyritic syenite	Porphyritic granite (sometimes called granophyre)	Porphyritic granodiorite	Porphyritic diorite	Porphyritic gabbro (also called diabase or dolerite)	Porphyritic olivene gabbro (very rare)
Fine-grained porphyry. Mass of the rock fine grained but contains numerous larger crystals.	Porphyritic trachyte	Porphyritic rhyolite	Porphyritic dacite	Porphyritic andesite	Porphyritic basalt	Prophyritic olivene basalt
Fine grained. Individual mineral grains too small to distinguish with the unaided eye.	(microscope classification)					
	Trachyte	Rhyolite	Dacite	Andesite	Basalt	Olivene basalt
	(field classification)					
	Felsite				Basalt	

TABLE 3-16—TABLE OF SEDIMENTARY ROCKS

	Clastic sediments			Chemical sediments	
	Mainly quartz	Quartz and orthoclase	Quartz and dark minerals	Calcite predominant	Dolomite predominant
Coarse grained, fragments larger than 1/16 in.	Conglomerate (if fragments are rounded) Breccia (if fragments are angular) Conglomerate may be composed of rock or mineral fragments	Arkose conglomerate (if fragments are rounded) Arkose breccia (if fragments are angular)	Graywacke conglomerate (if fragments are rounded) Graywacke breccia (if fragments are angular)	Coarse crystalline limestone	Coarse crystalline dolomite
Medium grained. Individual fragments between 1/16 and 3/1000 in.	Sandstone	Arkose sandstone	Graywacke	Limestone	Dolomite (used as both rock and mineral name)
Fine grained. Individual fragments smaller than 3/1000 in.	Shale	Shale	Shale	Fine-grained limestone	Fine-grained dolomite

TABLE 3-17—TABLE OF METAMORPHIC ROCKS

	Coarsely layered	Finely layered	Granular
Coarse grained	GNEISS	SCHIST	METACONGLOMERATE: If composed of rounded mineral or rock particles. MARBLE: If composed of calcite or dolomite. GRANULITE: If nondescript or composed of several species.
Medium grained	GNEISS	SCHIST	QUARTZITE: If composed mainly of quartz. MARBLE: If composed of calcite or dolomite. GRANULITE: If composed of several species or nondescript.
Fine grained	PHYLLITE	SCHIST: If composed mainly of mica or mica-like minerals. SLATE: If composed of dense unidentifiable minerals.	QUARTZITE: If composed mainly of quartz. ARGILLITE: If nondescript or if formed of clays or feldspars.
	Special rock names		
	AMPHIBOLITE: A rock composed almost entirely of amphibole.	PYROXENITE: A rock composed almost entirely of pyroxene.	GREENSTONE: A rock composed of serpentine, epidote, talc, chlorite, etc., predominantly green.

CHAPTER 4 — ORE ANALYSIS

By
RALPH I. SMITH

INTRODUCTION

The small-mine operator is concerned with simple and complex ore analyses. Relatively uncomplicated methods can be used at the mine site by the owner. Those that require expensive and complicated instrumentation are better left to established laboratories. The first group includes fire assaying, chemical analysis, panning, microscopic examination, use of ultraviolet or 'black light', colorimetric analysis, and use of radiation meters. The second group includes atomic absorption, x-ray analysis (both diffraction and fluorescence), spectrography or spectro-chemical analysis, polarography, flame spectrometric analysis, and several newer methods such as chromotography, ion exchange, chelation, neutron diffraction, and infrared spectrophotometry.

The word 'assaying' normally brings to mind the method known as fire assaying, the method universally used in the past for the determination of gold and silver. Recently a new method of analysis — Atomic Absorption, commonly called 'AA' — has come into use. The new method has virtually taken over routine analytical work. An ore containing gold or silver or both can be evaluated rapidly, accurately, and easily by either method.

Gold and silver are sold on the basis of troy ounces, and assays of these metals are reported in troy ounces per short ton of dry ore. A troy ounce is 480 grains, whereas an ordinary avoirdupois ounce is 437½ grains. The grain was originally based upon the weight of a 'plump grain of wheat' but is now established as 1/7,000 of an avoirdupois pound. A short ton is 2,000 avoirdupois pounds. There are 29,167 troy ounces in a short ton. These units are in use today, but as the United States changes over to the metric system, new units must be established.

Fire assaying, especially for gold, is extremely sensitive. One hundredth of an ounce (0.01 oz.) of gold per ton in regular ores is easily determined. This means that we can accurately determine 0.01 of 29,167 parts of the ore, or 1 part in 2,916,700 or 1 part in 2.9 million. In money value, if gold were selling for $150/oz. (the price may vary over a wide range), the assay is accurate to $1.50/ton. The standard weight of sample used is called the assay ton (AT) and is 29.167 grams. The sensitivity of the assay can be increased by using larger samples, a method often used on mill tailings for close evaluation. As an example, suppose that 1 AT of a tailing sample is assayed, and the resulting gold is found to be less than 0.01/oz. per ton. From this, we know that the tailings contain less than $1.50 of gold per ton but we do not know the exact value. The assayer will then test 5 AT. If the resulting gold weighs the equivalent of 0.02 oz., we divide by 5 to arrive at 0.004 oz./ton. Thus, the gold in the tailings is worth 60¢/ton (again assuming a gold price of $150/oz). This method of assaying more than one AT is used on ores only when precision is needed and the extra cost is justified. It is used regularly in assaying gold cyanide solutions, however, as no extra cost is entailed.

Atomic absorption is also extremely sensitive. The results are usually reported in parts per million (ppm) or parts per billion (ppb). The results are then recalculated to troy ounces per ton.

For ores, four classifications of samples are used. These are: (1) mine samples, used in selection of ore for mining and setting the grade of the ore, and for exploration and evaluation of ore reserves, (2) ore going into a mill, or mill heads, (3) control samples for settlement between seller and buyer, and (4) umpire samples to settle disagreements between seller and buyer.

In mine sampling, the operator wants to know the value of large blocks of ore. One sample per set or several cubic yards of rock will evaluate the unit well enough to show whether it is worth mining. It is usual to run one assay of half an AT. If the sampling is accurate, the one sample is sufficient for preliminary evaluation.

In milling, the operator needs more accuracy to determine input and outgo, or to keep a metal balance. The general practice is to assay duplicate samples of ½ or 1 AT each, depending on the amount of gold in the ore and the sensitivity required. One AT is used for low-grade ores and ½ AT is used for medium-grade ores. Running duplicate samples provides a check of the sample and the assay; the duplicates should check within 0.02 oz./ton for ores of milling grade. The average of the two samples is the value used for the ore.

Control samples are those made up by the smelter from a shipment by an independent owner (or small-mine owner). The whole shipment of ore is sampled by an automatic sampler, which crushes the ore and cuts a preliminary sample of 50 to 100 lb. This portion is then ground and cut to about 10 lb. The 10-lb. sample is put through a 100-mesh screen and mixed thoroughly. From it are cut four 'pulp' samples. The smelter assays one of the pulp samples. The result is sent to the mine owner, along with a second pulp. The third pulp goes to an umpire assayer, if necessary, and the fourth is kept in reserve for three years, as required by law. The smelter and the mine owner may run as many assays as they deem necessary to properly evaluate the ore. Control assays must be accurate, so special precautions and checks are used. These procedures raise the cost of control assays.

If the assays of the buyer and the seller do not agree, to the satisfaction of the seller, he may call for an umpire assay. He designates a custom assayer for the job, and the smelter sends the pulp samples saved for this purpose to the designated assayer. The umpire assayer then runs as many samples as he deems necessary for accurate results. This is an important assay and must be the best quality, hence the umpire assay is likely to be the most expensive. Settlement is made on the umpire assay, and the party whose assay is farthest from the results of the umpire must pay for the umpire assay.

One type of check assay that the small-mine owner can use cheaply and conveniently is called a composite-sample assay. For example the mine sampler takes ten mine samples, each about the same weight. After they are crushed and mixed, an equal amount of each sample is extracted and the ten equal parts are put together to make one 'composite' sample. The eleven samples are assayed separately. The average value of the ten original samples should very nearly equal the value of the composite sample. The limits of check can be established after the procedure has been used for a short period of time. If the results of future assays do not check within the established limits, an error has been made.

Another type of composite sample is often used with a screen analysis. The sample is prepared and assayed normally. A weighed portion of the sample is then put through a series of screens of different sizes. The amount of material retained by each screen is weighed and assayed. The value of each screen fraction multiplied by its weight is calculated. The results of the fractions are added, and this value should approximate the value of the original sample within reasonable limits. Again, if the values are not close, an error is indicated.

One precaution is necessary when dealing with gold ores that contain relatively large particles of free or metallic gold. Free gold will not grind in sample-grinding machines; rather it will flatten out and remain in large flakes, which will not go through a fine screen. All ores should be tested for such gold, called 'metallics'. The material remaining on the screen is removed, put in dilute nitric acid, and the acid boiled for a short period of time. If gold is present it will not be dissolved but will be cleaned so that it can be recognized. This gold is then weighed, and a prorated value—based on the total weight of the pulp sample—is added to the amount of gold determined in the assay of the pulp.

The methods and procedures outlined above apply equally well to the assay of silver ores except in one important detail. Silver is not as stable as gold when heated for assaying. Therefore, the losses of silver are greater than those of gold. These losses can be evaluated by what is called a 'correction assay'. Corrected assays are applied to assays of metallic silver (bullion), but not to the assays of ore, because the smelter loses more in smelting than the assayer does in assaying. Thus, the smelter will not base its payment on a corrected assay. Because silver is not as stable as gold, the margin of error allowed in assaying is larger. Duplicate samples of low-grade ores should check within 0.20 oz.; for ores containing as much as 100 oz./ton, the check should be within 0.5 oz.; the difference should be no greater than 1.0 oz. for higher grade ores.

Both fire assay and atomic absorption are rapid, economical, sensitive, and accurate. Atomic absorption is more sensitive than fire assay, but fire assay has the advantage that it simulates the conditions in the smelter furnace and thus gives an indication of how the ore will react in the smelting. Other methods can be used, but they are more expensive and complicated.

Fire assaying also discloses the presence of metals of the platinum group, platinum, palladium, ruthenium, rhodium, osmium, and iridium. Although these metals cannot be determined quantitatively by this method, the experienced assayer will recognize their presence as soon as the assay sample is taken from the furnace.

Determining which of the platinum group metals are present, and how much of each, requires a long and involved chemical procedure. The analysis can be run either chemically or by atomic absorption, but it is best left to an expert. Send such samples to a commercial laboratory that is equipped to do the job. If any metals of the platinum group are present in appreciable amounts, an analysis to determine their value may well be worthwhile.

Fire assaying has one other possible use, that is getting a rapid estimate of a few of the base metals in the ore. These metals are lead, copper, tin, antimony, mercury, and bismuth. Notice that this is an approximation; the error in the fire method is between 5 and 10 percent. It is a rapid method, however, and if no other is available, it can be used in prospecting. Because of the inaccuracies involved, smelters will not settle on a fire assay of the base metals.

For an accurate determination of all the common metals and impurities in an ore, chemical or wet methods of analysis are used. Wet methods employ water, acids, and various chemicals. A small sample of material is dissolved in acid, and the different constituents of the ore are separated chemically and evaluated. Generally, the amount of each metal or compound is reported in percent.

All metals and compounds of importance in smelting can be determined by the wet methods, especially if we regard atomic absorption as a wet procedure. A few of the common metals are copper, lead, zinc, iron, arsenic, antimony, and tungsten. A few of the compounds are silica or quartz, iron oxides, calcium carbonate (limestone), and aluminum oxide or alumina. Some methods of wet analysis are described later in this chapter.

Many of the ores evaluated by these methods contain more than one valuable metal. After the metals in such ores are identified, the mine owner may send a sample of his ore to a laboratory for tests to determine how the maximum value of the ore can be obtained. These tests are known as mineral-dressing and metallurgical tests. Commercial laboratories can run such tests at a nominal cost and can determine the costs and recoveries, thus giving the mine owner an idea how to market his ore to the best advantage.

The methods of analysis described above are the standard methods used by almost all smelters to evaluate ore. They are established procedures that can be relied upon. The cost of these determinations is small, and when done by competent workers the results are accurate and can be obtained rapidly.

The remaining methods of analysis are used in prospecting, in determining the characteristics of an ore so that processing can be improved, or are special methods of analysis used by commercial laboratories to determine something that cannot be obtained by the usual methods.

The first of these methods useful in prospecting is ordinary panning. Panning can be used in estimating the value of gold, silver, copper sulphide minerals, lead ores, zinc ores, and any other mineral aggregate, the specific gravity or density of which differs appreciably from that of the gangue. Put in water, the lighter minerals can be washed away from the heavier minerals. With careful sampling and weighing, the residue from panning permits a good estimate of the amount of valuable minerals present. Thus, a gold placer deposit can be evaluated by drilling and then panning the drill cuttings. Experience enables one to use panning as an accurate and economical method of evaluating placer gold deposits. Panning can be applied in the same manner to many other kinds of mineral deposits. Another use of panning is mill control. The tailings may be panned rapidly and often to determine the efficiency of the mill. With a little imagination and ingenuity one can use this method in many applications.

Microscopic examination involves identification of minerals by sight under a microscope, and can only be done by a person experienced in such work — a good mineralogist. After the various minerals are identified, the amount of each can be estimated. The method is rapid and positive for both ore and gangue minerals. An ordinary stereobinocular microscope (there are many types on the market) can be used. A small sample of the material is crushed to —250 and +325 mesh and examined. After identification, a particle count is made, from which the amounts of the various minerals present can be estimated.

Microscopic examination has several other advantages. The physical condition of minerals in the ore can be determined; for instance, a sulphide mineral such as pyrite or chalcopyrite may be weathered (oxidized) and, if so, coated with an oxide product, and so may complicate the milling process. The effectiveness of the grinding operation in freeing the ore and gangue minerals is easily ascertained by the microscope. Or, if losses of ore minerals are high, the reason can often be determined by microscopic examination. Perhaps the ore mineral is so fine and evenly distributed throughout the gangue material that the grinding required to free it would cost more than the value of the mineral recovered. A chemical or fire assay either dissolves or melts the material of the ore; consequently, particles, atomic or molecular in size, are separated, but this does not reveal the physical condition of the minerals. The physical condition can be evaluated only by visual examination with a microscope, but as stated above, this work can be effectively done only by an experienced mineralogist.

The polarizing microscope is another useful instrument. The light entering this microscope is polarized or made to vibrate in only one direction. Under this condition, the light coming from the mineral sample, either transmitted through the sample or reflected from it, gives various optical effects that are characteristic of each individual mineral being examined.

Two kinds of samples are used for this type of examination. For most sulfide ores, a polished section is made by cutting a specimen and then polishing the cut face to an absolutely smooth even surface, enabling the opaque minerals to reflect light directed on them. For the study of transparent minerals, a 'thin section' is made by cutting a very thin slice from a specimen. This slice is mounted on a glass slide. The polarized light is transmitted through the specimen. The optical effects of each mineral are characteristic of that mineral alone, hence a **trained operator** can positively identify a host of minerals, and can get much useful information concerning the physical condition of the minerals present in the sample. A semiquantitative estimate of the amounts of each mineral present can be made. As optical equipment is expensive and requires a trained operator, it may not be available at many mines. Samples can be sent to a commercial laboratory for examination at a reasonable fee.

Mineral fluorescence can be used as an aid in analyzing ores, as some minerals have the property of fluorescing under ultraviolet light. Ultraviolet, or 'black light' as it is sometimes called, is invisible to the human eye, but when directed onto a fluorescent mineral in a dark room or in subdued light, the 'black light' is reflected back as visible light, which appears to glow from within the mineral. Fluorescence of most fluorescent minerals is erratic, but some minerals have a fluorescence characteristic enough to be used for identification. Some of these are: autunite and a few other uranium minerals, greenish yellow; willemite, zinc silicate, green; scheelite, calcium tungstate, bluish white; zircon, zirconium silicate, orange; fluorite (not all specimens), calcium fluoride, purple (or other color); powellite, calcium molybdate, cream color; some diamonds, fluorescence variable; hydrozincite, hydrous zinc carbonate, blue. There are many minerals that have a characteristic fluorescence only in certain localities, thus fluorite from Clay Center, Ohio, fluoresces cream color, and that from Cumberland, England, fluoresces purple. Fluorescence can be used for estimating grades of ore, but commercially, it is used chiefly in hand-sorting ore from waste, and in this respect is a rough analytical method.

In connection with the black light, the geiger counter or the scintillation counter may be used. This instrument is useful for the detection of radioactive minerals. These include minerals of uranium and thorium. A few of the common elements, such as potassium, that have slight radioactivity, may register on such an instrument, especially in areas of hydrothermal alteration.

The geiger counter must be brought into close proximity to the material to be tested before it will work. It is generally carried by the person using it. Radioactivity is indicated by audible clicking of an earphone attachment or by a needle on a dial. Either of these indicators can be used at the discretion of the operator. As there is a small amount of radioactivity everywhere, called background, and the amount of this radioactivity varies from place to place, the background count for any locality must be established before an accurate estimate can be made of any abnormal radioactivity. Any indication above this background means radioactive minerals are present. If the count is very high, the clicking becomes a steady hum or the needle may go off the dial; a very active material is indicated.

There is no way of telling from the geiger counter which mineral is present. Quantity present can be estimated from the intensity. Radiometric analyses can be made by comparing given quantities of unknown samples with known standards; however, this does not give the absolute quantity of uranium or thorium present, but merely gives the uranium equivalent. If the ore is geologically 'young' and not in 'equilibrium' a radiometric assay is valueless.

A chemical analysis for uranium is usually reported in percent of uranium oxide (U_3O_8). Thorium is reported as thoria or thorium dioxide (ThO_2). These are units selected by the Atomic Energy Commission as a base for reporting and settlement.

The scintillation counter is used in the same manner as the geiger counter, but it is a much more sensitive instrument. It may be used in an automobile or an airplane. It can detect radioactivity from a considerable distance. Again, however, the scintillation counter must be supplemented by chemical or other kind of analysis to identify the metal and measure the amount present.

A reliable geiger counter costs about $100 or more, a scintillation counter $250 or more. Both are delicate instruments. They must be handled carefully and, to function properly, they must be serviced regularly by a trained technician. Handled properly, they are valuable tools for the prospector interested in radioactive minerals.

In the last few years the x-ray machine has been developed into a valuable tool or instrument for analysis. This is a costly and extremely complicated instrument. Also, a skilled and experienced operator is needed to obtain reliable results. Samples for x-ray analysis should be sent to a commercial laboratory.

For the small-mine operator either of two types of x-ray analysis could be useful—diffraction and fluorescent analysis. Let us look at diffraction first. The sample of material is ground to fine powder and then irradiated by or subjected to x-rays. Each substance or component present will then give off a characteristic pattern of radiation, which can be recorded on a film or picked up by a geiger or scintillation counter and recorded on a strip chart. From this record the operator can usually identify the materials present in the sample. If the material is complex—many substances are present—it may have to be treated chemically or mechanically to separate the substances for positive identification. Many methods of sample preparation and separation have been developed, so that all of the common minerals can be identified positively. Quantitative analyses can be made by x-ray diffraction, but the procedures are so complex and involved that the cost is high. Generally, the use of x-ray is restricted by cost and complexity to analyses that cannot be made by other, more economical methods.

Some examples of the profitable use of x-ray diffractions are:

1. The determination of the type of clay present in a given clay. The determination is rapid and economical. From this and experience based on a correlation of other physical tests, the behavior of the clay can be forecast with accuracy.
2. The identification of troublesome compounds and impurities in an ore.
3. The identification of the principal valuable minerals in an ore, which could be of help in the processing of the ore.
4. The detection of small amounts of some valuable mineral that otherwise might not be found.

Before a sample is submitted for x-ray analysis, however, an expert should be consulted to ascertain whether the necessary expenditure would be worthwhile. The cost of the analysis is high, there is a chance of misinterpretation by the inexperienced layman, and the information obtained might be of no direct value to the mine owner.

X-ray diffraction analyses are usually reported as the mineral or minerals present, if only identification is requested. If a quantitative analysis is made, the result is reported in percent of each mineral present, which is comparable to the report from a chemical analysis. X-ray machines are used to good advantage by many large companies but at present are too costly to be considered as a regular assay tool by most small-mine owners.

The second type of x-ray analysis of value to small-mine owners is called an x-ray fluorescent analysis. The instrument is called an x-ray spectroscope. The newer spectroscopes can detect sodium and the metals heavier than sodium. Older models can detect only titantium and heavier metals. For example the metallic element beryllium will not show. To detect beryllium a diffraction analysis would be used, which would indicate the presence of a beryllium mineral. With the spectroscope, the state of the metal beryllium is of no consequence. If an element that can be detected is present in any free form, combined in liquid solution, or even in the gaseous state, its presence can be detected. The only limitation is the amount present. The critical amount varies with the element, the other elements present, and the sensitivity of the instrument.

The first use of fluorescent analysis is the identification of the elements present in a material. It can be used for most of the common ore minerals, such as those containing copper, zinc, iron, lead, and tungsten. If the material is a solid, it is ground to a fine powder, as for other analyses, and irradiated by the x-rays. If the material is a liquid or a gas it is put in a special container and irradiated by x-rays. Each element gives its own characteristic pattern from which it can be identified.

The second use of fluorescent analysis is the determination of the amount of a particular element present. Normally, complex procedures are necessary to first calibrate the instrument for quantitative determinations. It is therefore a time-consuming method until the standards are established. It is also a costly method. Its main advantages are the detection and semiquantitative or quantitative determination of those metals that are difficult to assay by the more common methods. In certain cases, much smaller amounts of some of the heavier metals can be determined more quickly and more accurately than by conventional methods.

Some examples of cases in which the x-ray fluorescent analysis is advantageous are:

1. In the semiquantitative determination of the rare-earth metals. This family of metals consists of lanthanum, cerium, praseodymium, neodymium, illinium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium. These metals have properties so much alike that chemical analysis is extremely long and difficult. A pattern of a sample containing several of these elements can be made with an x-ray spectroscope, and interpreted in a few hours. The same applies to other metals that are uncommon but in use today. These metals include hafnium, columbium (niobium), zirconium, indium, gallium, thorium, tantalum, and yttrium.
2. If the presence of a platinum group metal is found by fire assay, the metal (or metals) could be identified by x-ray fluorescent analysis and its amount estimated in about a day, whereas a chemical analysis would take at least a week.

Generally, this x-ray fluorescent procedure is used for the identification and quantitative determination of the more uncommon metals. If you have a problem that you think could be solved by this method of analysis, consult a commercial laboratory or a state or federal agancy about the advisability and cost of such analyses.

The report of an x-ray fluorescent analysis often poses a problem. The report will show practically all of the elements present in the sample. One or more of these will be an element or metal in which the operator is interested, and the rest will be what we will call impurity or auxiliary elements. The two important factors are the percentage of the wanted metal present and the value of the ORE of the metal. The value of the ore can be obtained from a trade journal or magazine, such as the Engineering and Mining Journal, a monthly publication of McGraw-Hill Co. The quotation for the ore may be given as percentage or 'units', and as so many dollars per unit. A unit is 1 percent and it may be of either the metal or the oxide of the metal. If the quotation is given as percentage or unit of the metal, the value of the ore is easily calculated (units times price). The same applies if units and price of the oxide are given. If, however, the price is given for units of oxide and the assay report is in units of metal, an estimation of the percentage of the oxide present can be obtained by multiplying the percentage of the metal by a factor of about 1.25. This will average out well for the heavier metals. The approximate value of the ore can then be calculated as explained above.

An example of the use of a metal oxide as a unit is that of tungsten; the unit here is tungsten trioxide, WO_3, which contains about 79 percent tungsten. Another is uranium oxide, U_3O_8, about 84 percent uranium.

In most ores, the impurities or auxiliary metals are present in fairly large amounts and generally they are of no value to such an ore. These elements include aluminum, iron, magnesium, barium, calcium, and silicon. If iron is present in quantity, preferably 50 percent or more, the deposit of ore still must be large (several million tons) to be of value. Much the same can be said for the other common elements such as aluminum, magnesium, and barium. The retail price of reagent-grade elemental or metallic calcium currently is approximately $22/lb. The ore of calcium, however, would be limestone (main mineral, calcite, $CaCO_3$) or gypsum ($CaSO_4 \cdot 2H_2O$). The value of these as ore is at best only a few dollars a ton; the materials are abundant and present the world over. The reason that calcium metal is costly is that it is extremely hard to produce, and the demand for it is exceedingly small. It is used in small quantities in laboratories for experimental purposes and in research. The yearly demand would not exceed a few tons. The same applies to silicon, whose ore is silica or quartz. Elemental silicon is expensive; it is hard to produce and the demand for it is small; whereas quartz is prevalent the world over and can be obtained for a dollar or two a ton.

Generally, the metal or metals for which the assay has been made are the only ones to consider when calculating the value of a special ore. If other of the rarer metals are present, the quantitites must be fairly large before they can be considered of value. If the mine operator has a question as to the value of any of the metals present, he should consult a state or federal bureau or college connected with the mining industry, or a smelter official.

Another special method of analysis available through a commercial laboratory is known as spectroscopic or spectrochemical analysis. This type of analysis uses that property of an element that causes it to give off light of a certain wave length when burned. The light from each element has its own distinct wave lengths. These wave lengths and the intensity of each wave length are recorded by the instrument. By reference to a standard, the elements present and the amount of each can be determined. The instrument is expensive, and a highly trained operator is needed to run and maintain the equipment.

Spectrochemical analysis can be used to the best advantage in determining accurately small or trace amounts of elements in minerals or metals. It is a method to be used for special cases in which chemical or other common means of analysis are not adequate. An example of an advantageous use is in finding a trace amount of an element that is causing trouble in the processing of an ore. The cost of such an analysis is relatively high, usually warranted only in special cases when other methods are inadequate.

If the mine operator has a laboratory or assay office, the colorimetric analysis is a rapid and accurate method. This method can be used for determining almost all of the common metals. Only regular chemical glassware and a few chemicals are needed, except for a few cases. Special chemicals needed for these are readily available from chemical supply companies.

The method is based on the color that a metal in a specific condition will give to a solution. The presence of the metal is determined by this characteristic color, and the amount present is determined from the intensity of the color. First a set of standard solutions is made up, each containing a known amount of the metal, the amounts varying over the range of concentrations normal to the process or ore. The unknown sample is then made up in the same manner as were the standard solutions, and when prepared, it is matched with its counterpart in the set of standards. The amount in the unknown is then the same as that of the matched standard. The analysis is normally rapid, and it is sensitive and accurate.

The colorimetric method can be used to good advantage in many kinds of mill control. It is rapid, can be performed by the mill operator, and is inexpensive. It can be used to judge the performance of a mill, to detect irregularities, and as a control. A good example of this is checking solutions in a gold cyanide mill. It is necessary if unwarranted losses are to be avoided in precipitating or taking out all the gold in the gold-bearing solution before it is returned to the leaching or dissolving circuit. The colorimetric test for gold can be performed in 10 minutes by the mill operator. The test is sensitive to less than 1 cent/ton of solution. Thus, malfunctions of the mill can be detected at any time there is a question, and serious losses can be prevented. A procedure for this test can be found in most assaying and cyanidation text books. Like procedures can be used for many of the common metals. References for the methods will also be found at the end of this chapter.

Besides the test-tube method of colorimetric analysis, many instruments are available. The instruments are relatively inexpensive and are helpful in that they take the human element of eye sensitivity out of the analysis. Before purchasing such an instrument, however, check its characteristics and make sure it will do the work you require. Such information can be obtained from the manufacturer or salesman, or from the chemistry department at a college. Many manufacturers will run preliminary tests to prove the instrument.

Two other special methods of analysis may be of interest to small-mine operators who have their own laboratory. These are polarography and flame analysis.

Polarographic determinations are based on the electrical properties of a metal when it is in a specific solution. Standard solutions are prepared and run. The test is recorded on a photographic film. A test run is then made on the unknown sample and the results matched with the standard. Once the instrument is set up and calibrated, rapid and extremely accurate determinations can be made. Solutions of any strength can be used. The method is used for almost all of the elements and many organic compounds. The instruments cost about $400 or more. They are well built and dependable. The main limitation of this instrument is that the operator must be well trained to get good results.

The other special method, flame analysis, is performed with an instrument named the flame photometer. The method would be of interest to the producers of nonmetallic products such as limestone (for cement), clays, barite, and similar products. The flame photometer is an instrument used to determine small amounts of the impurity metals in the above-mentioned materials. These impurity metals are sodium, potassium, lithium, strontium, and others. If numerous determinations of any of the above-mentioned metals are needed, the flame photometer has the advantage of rapidity, and effects a saving because of the time element. Chemical analysis of these metals is time consuming and expensive.

METHODS OF ANALYSIS

To set up an assay office, the logical sequence is to begin with incoming samples. The first necessity is a place to dry samples—an oven, an iron plate on top of a stove, an electrical heater, or other provisions. Next the sample must be crushed and cut. A small sample jaw-crusher is the most convenient to use; it does a good job and can be easily cleaned. Cleaning after each sample is imperative to prevent salting of samples. The crusher should be brushed and blown out with air. If no compressed air is available, brushing must be meticulous. If the ore is not sticky, samples may be crushed first, then cut and dried; but if too sticky, they must be dried first, then crushed and cut.

Cutting the sample is one of the most important steps; it determines whether or not the final sample will be representative of the whole. After crushing the sample, mix it thoroughly before cutting. The cutting may be done with a Jones Riffler, which is a sampler equipped with alternate slots running in opposite directions. There are usually at least twelve slots, which cut the sample into as many parts, half the parts going to one side and half to the opposite side. With careful performance this device gives a good average sample. The sample is cut in half each time it is run through the sampler, and one half is discarded. The procedure is repeated until the sample is reduced to desired size. If a riffle sampler is not available, coning and quartering can be used. This procedure consists of making a conical pile of the sample. The cone is then cut vertically into quarters. Opposite quarters, or quarters 2 and 4, are discarded. Quarters 1 and 3 are then remixed, and the procedure repeated until the sample is reduced to the desired size. If the sample is very large the alternate-shovel method may be used at the start. This consists of mixing the ore, then shoveling the material into a new pile, saving every third, fifth, or tenth shovelfull for the sample, the final cutting then being finished by one of the two methods outlined above. The usual size of sample used for assaying is one-half to one pound. Dry if necessary and grind to the desired fineness. Remember that the assay is only as good as the sample; if the sample is not representative, the assay will not be representative.

Grinding is usually done in a disc grinder, which is fast, efficient, and easy to clean. At the start of each day, the grinder should be brushed out, blown with air, and the plates cleaned by grinding a few pieces of barren quartz, old assay crucibles, or anything hard, which will scrub the plates. Reblow and brush, then grind the samples, cleaning after each sample. Generally the ore should be ground to pass an 80- or 100-mesh screen. If the presence of free gold is known or suspected, screen the sample to pick up this material, known as metallics. Large pieces of gold will flatten out in the grinder and will not go through a screen. If present, this gold should be cleaned in acid, weighed, and the weight prorated to the total pulp sample. If no free gold is present, the samples may or may not be screened at the discretion of the operator. An experienced assayer using a good machine can tell when his sample is ground well enough not to need screening. If the ore is spotty, duplicates will not check; finer grinding may be necessary, but the amount must be determined by experiment on each individual ore.

If a disc grinder is not available, a bucking board, a flat and smooth piece of iron or steel, about 1 inch thick and 2 by 3 feet in area, and a bucking hammer can be used. A strong back is also essential with this equipment.

If samples are coming from a mill or mine, and it is known that they vary in value, a sequence of preparing samples should be established. Using mill samples as an example, it is known that the tailings will be the lowest grade sample. Also, tailings are easily salted or are amenable to salting, therefore tailings or low-grade samples should always be prepared first in a clean machine. Other samples should follow in the order of their value. Another good method with tailings is to cut two samples. Process one to clean the machine. Discard this sample; it will have picked up any extraneous material, but its processing will protect the second sample from salting. If feasible, two sets of machines can be used for sample preparation, one exclusively for tailings, and one for other, high-grade samples. After the sample is ground, mix it thoroughly on a mixing cloth, or otherwise, and it is ready for assay.

FIRE ASSAYING

If the assay is for gold and silver, the following equipment and materials are needed: A pulp balance that will weigh accurately to 0.05 gram; a set of assay ton (AT) weights (these are special weights so made that 1 milligram is to 1 AT as 1 oz. troy is to 1 ton avoirdupois, thus, 1 mg of gold from an assay ton of sample indicates 1 oz. of gold per ton of ore); fireclay crucibles, 20-gram size for ½-AT charges, 30-g size for 1-AT charges, and 10-g size for smaller portions; 2- and 3-in scorifying dishes for special work. Chemical reagents or fluxes needed are: lead oxide, PbO; soda ash or sodium carbonate, Na_2CO_3; borax, $Na_2B_4O_7 \cdot 10H_2O$, or borax glass, $Na_2B_4O_7$ (borax glass is recommended for better fusion and economy); niter or sodium nitrate, $NaNO_3$, or potassium nitrate, KNO_3, which is preferred, because it does not pick up water as does $NaNO_3$; plain white wheat flour obtainable at any grocery store; and silica or quartz, SiO_2 (clear glass may be broken up and ground as a substitute). Whiskey bottles, usually prevalent around a mining camp, are a good source of clear glass.

For the sake of economy ½-AT samples are run (used) when possible. If the ore is an oxide ore, use a 20-g crucible. Put into the crucible 15 g of soda ash, 50 to 60 g of litharge, 5 g of borax glass, 1 g of silica, and 2½ g of flour. Weigh ½ AT of ore, place on top of reagents, and mix the contents by stirring with a spatula. When well mixed, tap sides of crucible to dislodge particles adhering to walls of the crucible, level the charge, and add a slight layer of borax glass. The borax glass is called a cover; it prevents dust loss and cleans the wall of the crucible. Enough crucibles are prepared to fill the furnace. For other types of ore, different proportions of the above reagents, called fluxes, are needed. This information is contained in a book entitled **Fire Assaying,** by Shepard and Dietrich, published by the McGraw-Hill Publishing Company.

Next a muffle furnace is needed. A muffle furnace is one that contains a refractory oven. The flames burn around the outside of the muffle; its contents thus are isolated from the flame. Such a furnace may be built or purchased prefabricated. To build such a furnace, a muffle and firebrick are necessary. Designs can be gotten from assay texts or manufacturers' catalogs. A muffle furnace can be built for $100 or more. Prefabricated furnaces cost $300 or more, but in the long run are more satisfactory. Whether the furnace be built or bought, a carborundum (silicon carbide) muffle is recommended. It has a long life, conducts heat better than any other muffle material, and gives better service. Although the initial cost is greater, it is more economical than muffles made of other materials.

The size of furnace is the next problem. First, determine the number of assays needed each day. Furnaces range in capacity from 12 to 90 crucibles. One assayer can process 20 to 50 assays per day depending on the circumstances. The furnace should be of such capacity that the assays can be handled in two furnace loads, or the furnace should handle one-half of the day's assays per loading.

Choice of the fuel for the furnace is important and depends first on availability. Natural gas, bottled gas, gasoline, fuel oil, diesel oil, coal, or electricity can be used. Electricity is good but expensive, both in the initial cost of the furnace and the cost of electricity as fuel. Natural gas is the most satisfactory and most economical if available. In isolated places, fuel oil, gasoline, or bottled gas are usually available. Of these three, fuel oil is generally cheapest, more easily handled, and less dangerous than the other two, although the original equipment to burn fuel oil is more costly.

To continue the assay process, while preparing the samples for fusion have the furnace heating up. The muffle should be at least cherry red (temperature is judged by color) before the crucibles are put into the furnace. The crucibles are loaded with crucible tongs, several varieties of which are available; the choice of variety is left to the operator. Asbestos gloves are needed when working around the furnace. The crucibles are heated for about half an hour, then the contents are poured into an iron mold. The number of molds available should be somewhat greater than furnace capacity to allow for occasional errors. After cooling, the slag is broken away from the lead button, and the lead pounded into cubes. Button tongs and a slagging hammer are needed for this operation, also an anvil consisting of a flat smooth piece of iron or steel 1 inch thick and 6 inches square or larger. The bucking board may be used, if one is available. Herman inquarts (lead containing a known amount of silver) are attached to the lead button at this time, if it is necessary to add silver to the assay.

Immediately after the crucibles are taken out of the furnace, the cupels should be put in for preheating. Then turn the heat down so that the furnace will be at the required temperature when the lead buttons are added. This temperature is about 950°C, which is indicated by a cherry-red color. Learn to judge these temperatures by studying color-temperature charts, which can be found in assay texts. Good temperature judging comes with experience.

Cupels are cylinders with a depression in the top to hold the lead while it is burned off. This operation separates the gold and silver from the lead, leaving them on the cupel in a round bead. The bead is removed and weighed, and the ore evaluated from the weight of the bead. Special cupel tongs are needed for loading and unloading the cupels.

Cupels are made of refractory materials. They can be purchased prefabricated or can be made by the assayer; the assayer commonly makes his own. Most purchased cupels are made of magnesium oxide and are relatively expensive. Home-made cupels are made of bone ash or bone ash to which has been added as much as 20 percent common cement. The choice here is left to the assayer. Bone ash can be purchased in four grades, X to XXXX; XXX grade is generally the most satisfactory for normal assaying. Bone ash cupels should be aged a few days before use to ensure complete drying.

Cupel-making machines can be purchased from an assay supply house. Three types are available, foot operated, hand operated, and compressed-air operated. Choice of type depends on economics and the assayer's preference.

After processing in the furnace, the cupels are cooled, and the gold and silver bead is removed with a pair of bead pliers. The bead pliers should be good; the beads are small and may be lost if not handled effectively. The beads are flattened with a metal mortar and pestle and placed in individual porcelain parting cups. Coors glazed parting cups or crucibles are most used for this purpose. Parting cup trays are needed to hold the cups. The combined gold and silver beads are then weighed to determine the metal content and replaced in the cups.

To separate the silver from the gold, called parting, the cups are now filled with dilute nitric acid and heated just under boiling, to dissolve the silver. To accomplish parting, a hot plate, asbestos pad, wash bottle, nitric acid, distilled or pure mountain water, stirring rod, tongs, a few beakers, and a blow torch or electric heating coil or similar device are needed. After the silver is dissolved, the solution of acid is poured off and the gold washed at least twice with distilled water. The cup is dried on the hot plate and then heated to red heat with the blow torch to 'anneal' the gold—bring the gold back to its natural color.

After cooling, the gold is weighed and the assay is complete. To weigh the gold and silver, a bead or gold balance is needed. This balance must be sensitive to at least .01 mg; many are sensitive to .002 mg. Other than sensitivity the choice is up to the operator. Many makes and several types are available, all of good quality and accuracy. New balances cost about $300 or more. Used balances may be purchased for less. If a used balance is considered, get a guarantee or pretest the balance. It is a precision instrument and must be in good working order to give accurate results.

A gold balance is a delicate instrument and must be handled with extreme care and must be kept clean. It should be located in a room isolated from the rest of the assay office. The temperature of the room should be maintained as evenly as possible. Keep the balance out of direct sunlight and covered when not in use. Also it must be mounted on a solid base to avoid vibration. The maximum capacity of a gold balance is 1 g; never exceed this weight, as it will ruin the instrument.

In addition to the balance, a set of milligram weights consisting of weights from 1 mg to 0.5 g, a small camel-hair brush, and tweezers, preferably ivory tipped, are needed.

To summarize, the minimum equipment needed for an assay office: a separate building of at least four rooms; crushing, grinding, and sampling machinery; a muffle furnace; furnace tongs, slag molds, cupel trays, slagging hammer and tongs, asbestos gloves, and anvil; pulp and gold balances, and weights; hot plate, blow torch, parting cups, cup trays, bead pliers, and metal mortar and pestle; laboratory pyrex glassware, fireclay crucibles, scorifying dishes, and cupels; and acids, chemicals, pure or distilled water, and fluxes.

ATOMIC ABSORPTION

Atomic absorption is based on putting the element being evaluated or determined into solution and into an atomic vapor, which is a ground, un-ionized, or unexcited state. The atomic vapor is then irradiated, the radiation being supplied by a hollow-cathode lamp with a cathode made of the element being assayed. With the lamp current on, the atoms of the metal within the lamp are excited and emit characteristic radiation. The atoms in the sample, in vapor and ground state, then absorb the radiation. This absorption can be measured and evaluated with standard solutions, and reported in ppb, ppm, or percentage of the element in the sample.

The apparatus or instrumentation needed for atomic absorption is usually put together in one main unit and several auxiliary parts. The main unit is composed of a burner designed to give a long thin flame and a system to spray the solution into the burner flame; a container to house a hollow-cathode lamp, which provides the light emission; and a container to house a monochromator, the detection instruments, and the dials and other apparatus necessary to give a read-out of the results.

The auxiliary equipment consists of several extra lamps, as generally a separate lamp is needed for each element, although some lamps may be used for as many as three elements; pressure tanks for fuel gases and oxygen, with the needed control gauges; a vent to carry out the combustion gases; and the general apparatus and chemicals needed for all analytical work. A chemist and trained operator are necessary for accurate and acceptable work.

The fuels most commonly used are: air-acetylene, nitrous oxide-acetylene, and nitric oxide-acetylene. Other fuels that have been used are: air-gas (gas includes several kinds of hydrocarbon gases), air-hydrogen, oxyhydrogen, oxyacetylene, and oxycyanogen.

The procedure consists of getting the wanted element into solution chemically, usually complexed or combined with an organic compound. The solution is then sprayed into the flame and burned. The burning puts the atoms of the element into the ground or unexcited state. During the burning, the atoms are subjected to or irradiated with light-emission lines from the hollow-cathode lamp. These are the lines of the spectrum peculiar to that element. The absorption of the emission lines by the atoms of the element being assayed is measured by the light detector, and the results are converted to ppm or the percentage of the element present.

Chemical procedures for the dissolution and complexing of the various ores before burning are usually supplied by the company that made the instrument, or they may be found in textbooks or in analytical literature. The general apparatus and chemicals needed for normal analytical work can be found in the section on Quantitative Chemical Analysis, which follows.

The procedures for the preparation and sampling of the ore are the same as those outlined above. These procedures are used for all sampling and are mandatory to make sure that a representative sample of the whole body is obtained.

QUANTITATIVE CHEMICAL ANALYSIS

Gold and silver may be associated with commercial amounts of base metals, such as copper, lead, and zinc, or a mine may produce a base-metal ore devoid of commercial amounts of gold and silver. Additional analytical equipment is needed to measure base metals.

Samples are prepared in the manner already described, with one possible exception. If steel from the disc grinder would contaminate the sample during the primary grinding, this steel would be removed with a magnet, and the final grinding accomplished with an automatic mortar and pestle or similar grinding machinery made of agate or mullite. Such cases would be rare and are not usually encountered in ordinary analyses.

Although procedures of quantitative or chemical analysis vary, three general methods are commonly used. The first of these is called the gravimetric method. The first steps of almost all ore analyses consist of a gravimetric determination of insoluble matter. Assuming the sample is dry, a small portion is cut and put into a weighing bottle, and the bottle is stored in a desiccator. A desiccator is an air-tight glass vessel that contains a moisture absorbent. The sample will not absorb moisture from the air under these conditions.

Two methods of weighing the sample for analysis may be used. If the ore is hydroscopic (takes up moisture from the atmosphere), weighing should be by difference. The filled weighing bottle, which is capped, is weighed. A portion of sample, usually about 0.5 g, is removed from the weighing bottle and put into a beaker. The weighing bottle is immediately recapped and reweighed; the difference in the two weighings is the sample weight. If the ore is not hydroscopic, a portion of the sample is placed directly on the balance pan and the weight adjusted to 0.5 g by addition or subtraction of material as necessary. A 0.5 g sample is commonly used, but larger samples can be used when necessary.

For such weighing, an analytical balance is needed. This balance must be sensitive to 0.1 mg at full load. It is a delicate and precise instrument, so it must be kept clean and handled much in the same manner as a gold balance. Analytical balances, however, will weigh much heavier loads than the gold balance; the maximum capacity will be specified by the manufacturer. Many types are available. Some of the newer types, put on the market in the last few years, can be operated more rapidly than the older types, which is advantageous if large numbers of analyses must be made in a day. The newer types have an integral weight system, whereas the older types have separate weights. Prices of new balances start at about $300.

The sample having been weighed and placed in a pyrex beaker, a solution of acid is usually added. Some ores are practically insoluble and must be fused before dissolution in acid. Such insoluble ore is mixed with a sodium or potassium salt, and the mixture is placed in a porcelain crucible and heated to a red heat in a fusion furnace. This furnace may be heated by gas, oil, or electricity. After fusion and cooling, the sample, still in the crucible, is put into a beaker and the acid added. The beaker is heated until all of the ore is in solution. A hot plate is needed here, and the solution is gently boiled until solution is complete. Usually the beaker is covered with a watch glass to prevent loss of the boiling solution.

After dissolution, the solution is evaporated to dryness, either on an asbestos-covered hot plate or in a steam bath. After cooling, another dissolving agent, usually acid of some kind, is added, and the sample gently boiled. At this point the so-called insol or insoluble solid matter is left. This consists of silica and alumina (SiO_2 and Al_2O_3). The solution is then run through a filter to remove the solid matter.

After all of the solution is washed out of the filter paper, the paper and solids are ignited. Ignition consists of folding the paper and putting it into a prefired constant-weight porcelain crucible and heating and crucible (supported by a ring, ring stand, and wire triangle), over an open flame, which chars and burns the paper without its flaming. This is continued until only white ash is left. The crucible is then fired for several minutes in the fusion furnace to a temperature between 700°C and 1,000°C. After cooling to about

100°C, the crucible is placed in a desiccator and cooled to room temperature. It is weighed and refired until a constant weight is obtained. The difference between the weight of the crucible empty and the weight with the charge is the wanted weight of insoluble matter. A pair of crucible tongs is necessary to handle the hot crucibles. Asbestos gloves are optional; usually a laboratory towel or piece of cloth is sufficient protection for the hands.

The foregoing procedure, with a few variations, is used for all gravimetric determinations. It is used in the determination of such solid materials as lead sulphate, barium sulphate, tungstic acid, molybdenum as lead molybdate, magnesium as magnesium pyrophosphate, and many other compounds.

The solution from which the insoluble matter was filtered is called the filtrate. Determination of the metals remaining in the filtrate may be made by one of three methods. If a pure insoluble compound of a metal can be formed, this will be done, and the insoluble compound treated as outlined above. If not, the metal will be put into a soluble chemical form such that it can be oxidized or reduced by the addition of an appropriate solution. The addition of this solution is known as titration, and the method is given the name volumetric determination.

The solution to be added is known as a standard solution, so-called because the amount of reagent in the solution has been accurately determined. The main piece of laboratory glassware needed for making such solutions is a calibrated volumetric flask.

To make a volumetric determination, the unknown solution is prepared. When ready, the standard solution is added drop by drop until the reaction between the two solutions is complete. This is usually indicated by a change in the color of the unknown solution. The color change is brought about by the addition of a chemical called an indicator. The indicator may be used internally or externally. The standard solution is added from a burette, which is a calibrated tube equipped with a stopcock. From the strength of the standard solution and its chemical relationship to the unknown solution, the amount of the metal can be calculated and determined accurately. Common laboratory glassware, the burette, volumetric flask, and a spot plate for external indicators are the equipment needed for such determinations. This method is used for the quantitative determination of such metals as copper, lead, zinc, manganese, iron, and many of the other common metals.

The third method commonly used in quantitative analysis is the electrolytic method. Special equipment, such as a source of direct electric current, automatic stirring devices, electrodes, and electrical wiring is needed. The equipment may be purchased as a unit called a titrimeter or electroanalyzer, or it may be made by the operator or analyst.

The electrolysis is carried out on a previously prepared solution of the metal to be quantitatively determined. After preparation, this solution is subjected to the electric current. This causes the wanted metal to deposit on an electrode known as the cathode. After a prescribed time, and after an appropriate test shows that all of the metal is deposited, the cathode is removed, dried and weighed. The difference in the weight of the clean cathode and the weight of the cathode and deposit gives a direct determination of the amount of metal present in the solution. This method can be used for copper, nickel, lead, gold, silver, manganese, and many other metals. It is a very accurate and rapid method of analysis where applicable. It is also economical if a large number of samples must be analyzed daily.

Besides these standard methods of analysis, colorimetric tests can be made for many metals, and no supplemental equipment is needed. Such tests can be used to check mill operations rapidly and economically and do not require a highly trained technician. Procedures for most of the common metals have been worked out and are readily available.

The methods recommended for rapid, accurate, and easily performed analyses with a minimum of instrumentation are listed below.

1. For iron—the dichromate or permanganate methods, the choice depending upon what other metals are to be determined and upon economics.
2. For copper—the short iodide-fluoride method and the permanganate method. The first is good for all percentages of copper. Also, the electrolytic method is fast and accurate, if feasible.
3. For lead—the molydbate method and the chromate method. The first is most used in the western states.
4. For zinc—the ferrocyanide method.
5. For manganese—the Volhard or permanganate method.
6. Colorimetric methods can also be used to good advantage in mill control for gold, silver, copper, and tungsten.

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CHAPTER 5 — MINE METHODS AND EQUIPMENT

By
KOEHLER S. STOUT

INTRODUCTION

The main objective of mining is to make a profit from the mineral that is excavated from the earth. In mining, as in any other business, either a profit results or the business ceases. In times of national emergency the government may aid essential business and often does subsidize certain industries. Some mining enterprises have benefited by a guaranteed price paid for a mineral, ore, or finished product. Nevertheless, the mine operator must still conduct his operations so that a profit results, even though he is helped by the government.

Mining is affected by fluctuating prices for its products, by fluctuating prices for necessary supplies, and by adversities common to all industrial enterprises. Mining is also affected by conditions peculiar to it alone. The first condition is that the potential source of income is restricted by the location, size, and value of the ore body. The second condition is time; not only does it take considerable time to prepare a mineral deposit for exploitation, but many deposits must be worked rapidly once they are prepared, lest the development openings be destroyed by natural forces. Thus, the time element must be carefully adjusted after the initial nonproductive development period is passed, so that further development will keep pace with production.

The basic economic equation in any business operation is profit equals receipts minus disbursements. In mining, we may express the equation in this form: profit equals value per unit times amount of ore, minus cost of producing and selling the product. Profit is the factor in which we are interested. It determines whether the mine is a success or a failure. Methods of determining the value and amount of ore in any deposit have been discussed under Ore Reserves. Unfortunately, however, we can not determine exactly the total amount or value of recoverable ore before mining operations begin. Therefore, we must decide whether there is a sufficient quantity to begin mining. If mining seems justified, then we must concentrate on the last part of the equation—cost of producing and selling the product. The factors that affect the cost can be grouped as follows:

1. Acquiring and prospecting the ore body.
2. Studying the possibilities of the venture.
3. Determining environmental and rehabilitation costs during and at the conclusion of mining.
4. Developing and preparing the ore body for production.
5. Plant and equipment.
6. Mining ore and bringing it to the surface.
7. Taxes, insurance, and other business expenses.
8. Milling, smelting, or otherwise preparing the mineral product for sale (including transportation from mine to mill or smelter).
9. Selling the mineral product (includes transportation to market).

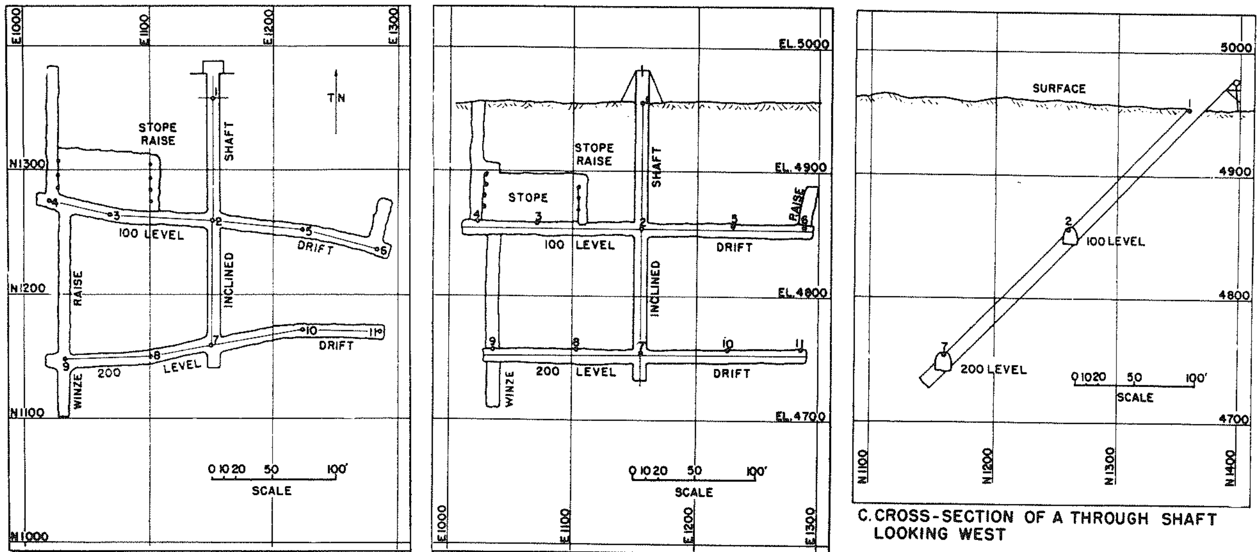
All these items must be considered, as all affect the profit picture.

The basic equation is set up for a total evaluation. That is, total profit equals total receipts minus total disbursements. In evaluating a mineral deposit, we must consider this equation because the total expected profit determines whether or not the venture is a good risk. For the actual day-to-day mining operation, however, the formula covers too long a period of time. The only way that one could determine the profit by the formula would be to wait until the mine is exhausted. This is not enough; we must know the state of business as we go.

To make this formula more useful, it is applied to certain periods or units of time — weekly, monthly, or yearly. If a profit does not accrue during one unit of time, the manager is in a position to determine why and to take immediate remedial steps. All of the previously listed contributing factors apply in the unit equation, as they did in the total equation. If one of the items is high during any one unit of time, this item can be studied and remedial steps taken to keep it in line. Some costs, such as equipment costs, construction costs, and certain other capital items must be divided by their useful life and distributed over several time units in the unit equation. This is known as amortization.

There are many different ways to open and prepare an ore body for production. The method selected should cost the least for development that will put the mine into efficient production. The proper choice of a development system is often a big factor in efficiency. In addition, the capital expenditures for mining equipment and development must be carefully considered, in order to avoid waste.

Much money can be lost by improper mining techniques or carelessness in mining. Recording



A. COMPOSITE PLAN MAP OF A MINE PROJECTED ON A HORIZONTAL PLANE

B. VERTICAL SECTION OF A ON E-W PLANE LOOKING NORTH

C. CROSS-SECTION OF A THROUGH SHAFT LOOKING WEST

FIGURE 5-1.—Plan and sections of a small mine.

the costs of an operation is a good check on efficiency. Usually, low costs go with high efficiency. Of course, recovery of as much ore as possible must also be considered. Just how far do you go with cost control in any operation? It can be overdone as well as underdone. A happy medium must be found that is applicable to small mines.

Taxes and insurance are a burden all businesses must bear. What taxes apply to mining? How does insurance affect mining costs? Can they possibly be reduced or controlled? These important considerations will be discussed from the point of view of the small-mine operator.

Our society has become very conscious of our environment in recent years. Many recent laws, both state and national, pertain to air and water pollution or to rehabilitation of the land during mining and after mining ceases. In many cases, several different state and national agencies have certain controls over mining operations, and all of these agencies must be satisfied or the operator may incur a fine and forced suspension of operations. Meeting these requirements is an added expense of mining and must be considered in the total cost analysis.

The cost of developing and mining ore is normally the largest proportion of the total production expense. Time spent in studying the factors affecting development and production costs should result in more profit to the operation. The selection of the mining method to suit the ore body, and the spacing of the development headings to fit the mining method are challenging problems. There are many possible ways to mine an ore body, but, for any given set of conditions, there is usually one best method.

One of the most important factors that affects any mining operation is time. Let us suppose that an ore body is found that must be developed through a shaft. Before any real development can start, the shaft must be sunk to the first working level. Shaft sinking is time consuming, and so is driving development headings necessary before actual mining can begin. Hence, to put a mine in production, months or even years may be spent in development work.

Scheduling is an important phase in mining, because of the time required for the different tasks. Ground has a tendency to weaken and cave, or supporting timbers may rot away. Experience has shown that in many places it is wise to mine out and abandon sections of the mine as fast as possible in order to cut down on maintenance costs.

Too often, the method used for ore recovery is found by the expensive trial and error process. A method is tried. If it does not work, another is tried, and so on until a workable one evolves. Although this may be quite unscientific, it is often done. Why? A partial answer is that the characteristics of the ore body that dictate the mining method are not known until actual mining starts. Examination of cores recovered from drilling may aid in anticipating the conditions to be encountered. Science is progressing in the field of rock mechanics so that we may be further helped in selecting the mining method by testing the rocks. Information so obtained may aid us in selecting the mining method, but the final test comes when operations commence and we can see how the ore and wall rock respond to our method. In some places 'trial and error' is the only answer, but if we can use other ways, we should.

Figure 5-1 shows a series of plans of a mine with the usual mine terminology.

Shaft.—A shaft is a vertical or inclined excavation from the surface, of small cross-section area compared to its depth. It provides access to the underground workings of a mine.

Winze.—A 'shaft' driven downward from an underground working.

Level.—Collectively the horizontal, or nearly horizontal, passageways or headings at the same approximate elevation; commonly interconnected. Levels are usually 100 to 200 feet apart and are designated either by their distance from the collar of the shaft, by their actual elevation above sea level, or by some other mode of reference (Fig. 5-1). A crosscut is a horizontal heading driven either at right angles or at a large angle to the strike of a vein. A drift is a horizontal heading driven in or along the course of a vein. A drift is most generally thought of as driven in the vein, and a lateral is a horizontal heading driven along a course parallel to the vein, usually in the footwall, and chosen because ground conditions are better. Crosscuts are driven from the lateral to intersect the vein at specified intervals.

Raise.—An excavation of small cross section driven upward, either vertically or at an angle. The primary purpose of a raise is to provide access to and from stopes, but some are driven for ventilation, or as ore, waste, or supply passes. Some are maintained (often serving some other purpose) as secondary (escape) passageways.

Stope.—Any underground excavation the primary purpose of which is to remove ore, the previous mentioned development workings excepted. The outline of a stope is commonly determined either by the limits of the ore body or by drifts and raises. There are many varieties of stopes.

MINING METHODS

Because this handbook is intended primarily for operators of mines producing less than 250 tons per day, large-scale mining methods will not be described; only the methods most commonly used in small mines will be discussed.

SURFACE METHODS

In open-pit or strip-mining operation, the ore is removed by surface excavation. Although there are no overhead ground conditions with which to contend, there may be side or slope pressures that cause concern.

Open-pit mining is usually cheaper than underground mining, provided the ratio of waste to ore does not become too great. Larger and heavier equipment can be used, which tends to reduce unit costs. Bad ground conditions seldom hamper operations in an open pit; where there is side pressure, trouble can be eliminated by keeping the side slopes flat. The safety record tends to be much better than in underground operations. Open-pit mining is applicable to most large ore deposits, but under favorable conditions, open-pit methods may be used to obtain enough money to start underground operations, even though the deposit is small. If the outcrop is properly situated so that it is mineable by open-pit methods, the first ore from the mine may be produced by this means. Equipment used in a pit may be rented, thus saving the large initial cost.

A typical cross-section of an open-pit operation using power shovels and trucks is shown in Figure 5-2. The length and height of the benches will vary according to the size of the units involved and the characteristics of the ore body. If mining is started without regard to the layout and design of benches, soon the ore body is being mined in a deep pit with steep rock walls on two or three sides; then it becomes necessary to bench, go to underground methods, or abandon the pit. Starting benches at this time is slow, dangerous, and expensive. It would be much better to start the waste benches soon after the pit is started; such procedure saves time and money. Of course, the extent of an ore body may not be known, but if the valuable constituents in the ore seem likely to hold up at depth, benches should be started at an early date.

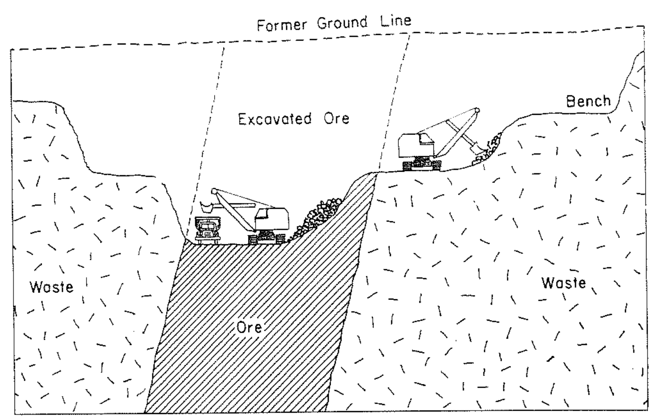


FIGURE 5-2.—Cross section of an open pit.

The waste-to-ore ratio means the ratio of the amount of waste stripped for each ton of ore mined; for example, a 2:1 waste-to-ore ratio means 2 tons of waste are removed for every ton of ore mined. The following example will show the importance of this relationship.

Let us assume that a continuous vein averages 20 feet wide and $10.00/ton in valuable minerals. The following costs, though by no means standard, are assumed:

Milling cost	$3.00/ton	Fixed cost
Marketing cost	$ .50/ton	Fixed cost
Overhead costs	$1.00/ton	Fixed cost
Mining costs	$1.00/ton	(whether ore or waste)

The fixed cost against a ton of ore is $4.50 before it is mined. The mining cost, which includes drilling, blasting, loading, and transporta-

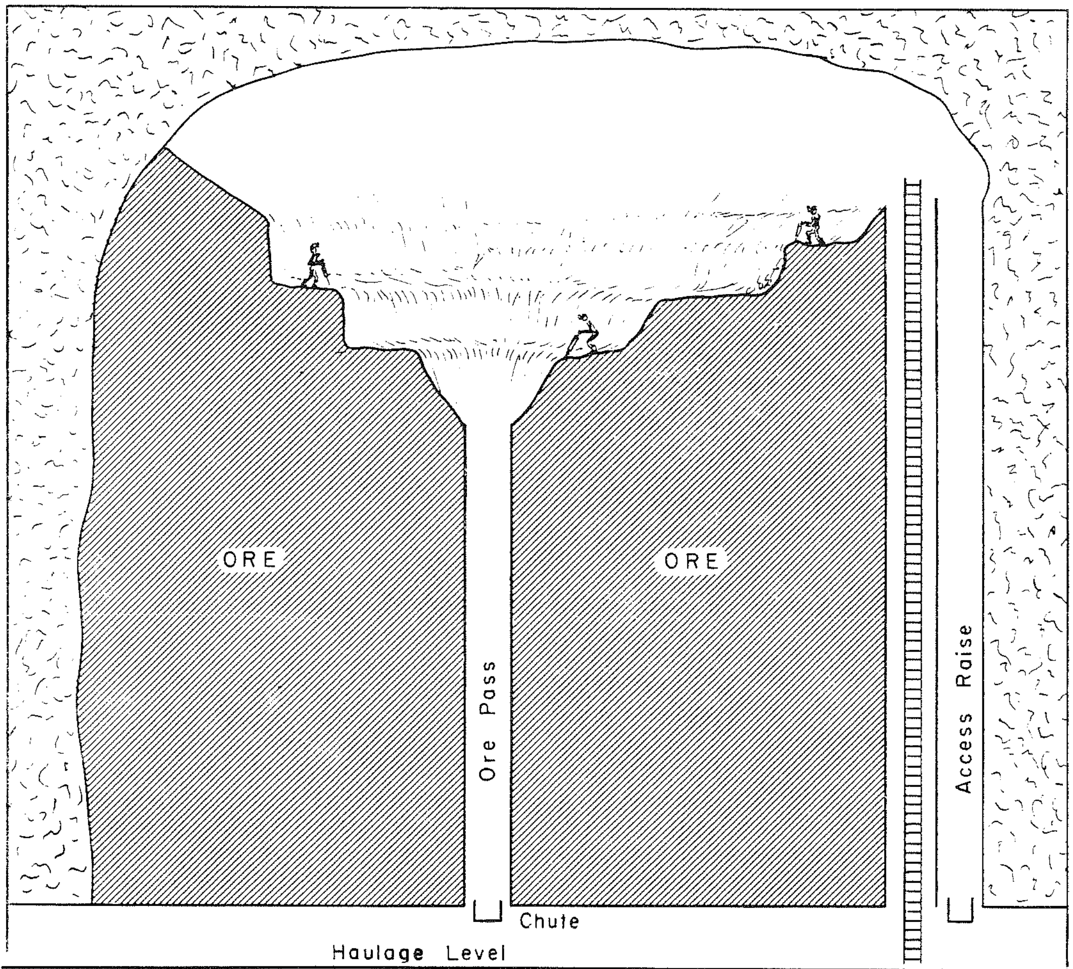


FIGURE 5-3.—Cross section of underhand glory hole stope.

tion, is $1.00/ton. The waste must be broken and hauled out of the way just as expensively as the ore. If the waste-to-ore ratio is 3:1, the mining cost is $4.00/ton of ore produced. That is, 4 tons of material is mined, 3 of waste and 1 of ore. 4 × $1.00 = $4.00. If the waste-to-ore ratio gets much greater than 4:1, mining cannot be continued profitably at this pit. The question then arises, how high and wide can the benches be? The answer depends on the ground conditions. If the wall rock is hard and firm, benches can be narrow, but if the ground is fairly soft and weathers easily, benches must be wide or sloughing material will endanger the men below. Even in hard ground, the overall slope should not exceed 60° if the pit is to be more than 100 feet deep, except in unusual circumstances.

UNDERGROUND METHODS

Open Stopes.—Authorities divide open stopes into four categories: Gophering, glory hole, stull, and pillar.

In gophering, the ore is closely followed regardless of its course. It is not a planned mining method, because it has no system. It is used in small irregular high-grade ore deposits. Being irregular, the workings in gophering are inconvenient for ore disposal and supply intake. For small, narrow, high-grade stringers, this may well be the best method. In comparison with other mining methods, gophering is likely to produce the least ore per man shift.

The glory-hole method is somewhat similar to open-pit except that the ore is extracted from underground. It may be mined from the surface or underground. To develop a glory-hole system, a raise (or series of raises) is run through an ore body. From the raise, enlarging takes place at the top of the ore body and continues progressively downward. Benches or walkways are left at the side of the excavation for travel and access to the working area as the ore is mined out. See Figure 5-3 for an underground glory hole. This is called an underhand stoping system, that is, all work progresses in a downward or 'underhand' direction.

The physical requirements for this system are strong, firm, self-supporting walls and overlying

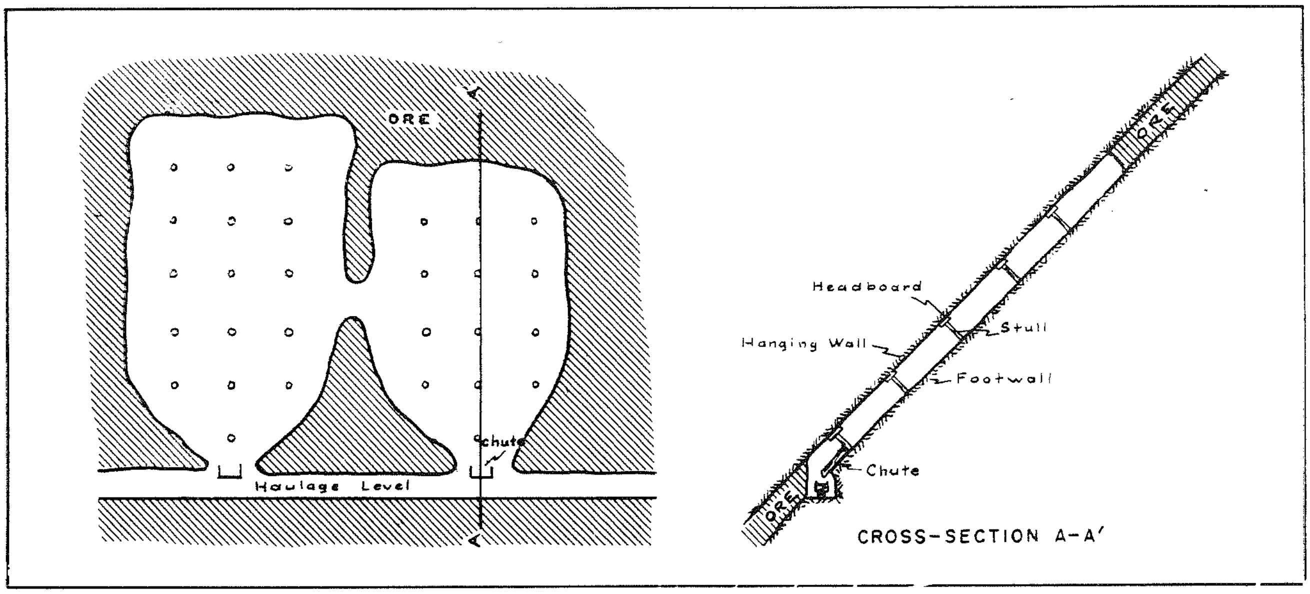


FIGURE 5-4.—Plan and section of the stull-type system of stoping.

cap rock. Once the ore is worked out, there is no way to reach the walls or back unless preparations are made to do so as the ore is mined. This could be done by installing catwalks along the back. With modern safety rules it is doubtful that this system could be used today, unless the deposit had a small diameter. If this method can be used, however, it produces much greater tonnage per man shift than gophering and results in lower production cost.

A stull stope is an open stope in which timber stulls are used to support bad parts of the hanging wall or to provide a platform for mining operations. Generally a systematic placement of stulls is better than an irregular method, because more of the wall will be supported. Little development is required for this method, other than a chute or chutes at the bottom of the stope, and it is used especially where the ore shoots are short. The sketch (Fig. 5-4) shows one typical example of this method, but there are many variations that are practical. The ground should be firm for this method of stoping. Rock bolts, or a combination of stulls and rock bolts, are sometimes used in place of stulls for support in some sections. Stull stoping is a cheap method of mining by comparison to regular timber systems but is more expensive than the open-stope methods because of the cost of stulls and the time required to install them.

The pillar stope is similar to the stull stope except that part of the ore is left unmined to give

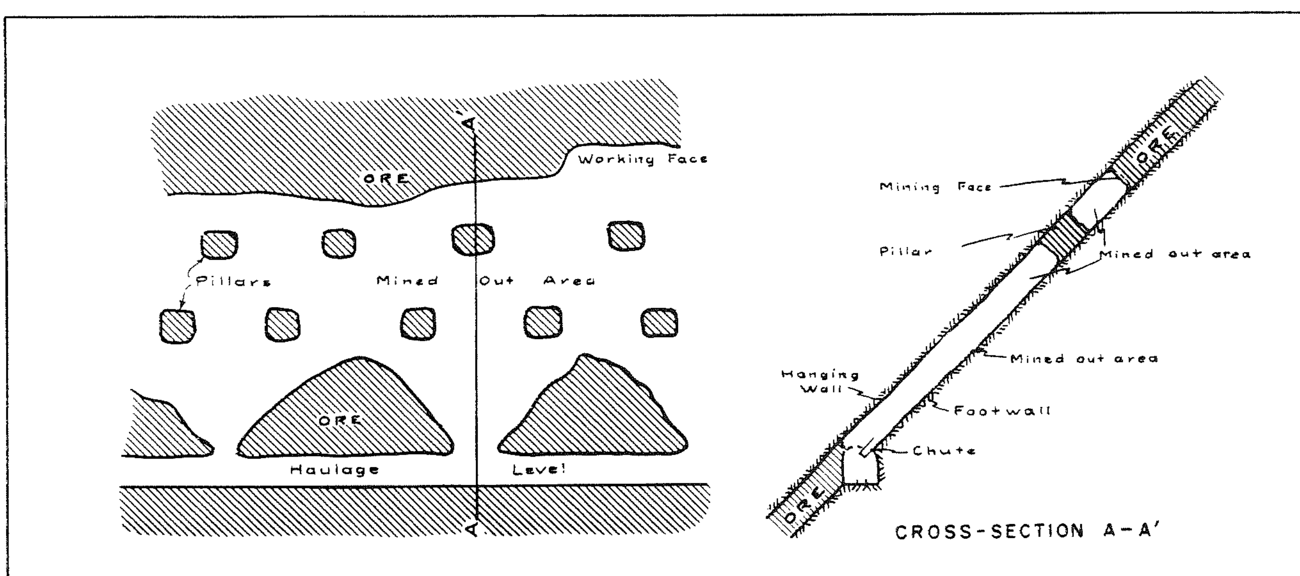


FIGURE 5-5.—Plan and section of the pillar-type system of stoping.

support to the hanging wall. As in the stull method, a regular pattern of pillars is more efficient than an irregular one. The exact spacing of the pillars will vary widely and is dependent on ground conditions, but the ground should be firm and hard. The preparations for starting this method are similar to those for a stull stope, and a stope can be started on short notice. This system may be worked in conjunction with stulls; low-grade portions of the vein are left as pillars, and stulls or rock bolts are used in higher-grade portions for support (Fig. 5-5).

In both of these methods, it is good practice to mine out a stope as rapidly as possible and abandon the area. In time, most openings will close up or cave; the time element is important. The room-and-pillar system is used for most flatlying or nearly flatlying ore deposits and in coal mining and in other bedded deposits where artificial means of support would be too costly.

Shrinkage Stope.—The shrinkage-stoping system (Fig. 5-6) can be used in a vein where the ore is hard and does not pack readily. The walls must be hard and firm so they will stand over large spans without support. In shrinkage stoping, the broken ore provides a platform from which to work. Owing to the fact that ore increases in volume about 40 percent when broken, some of the

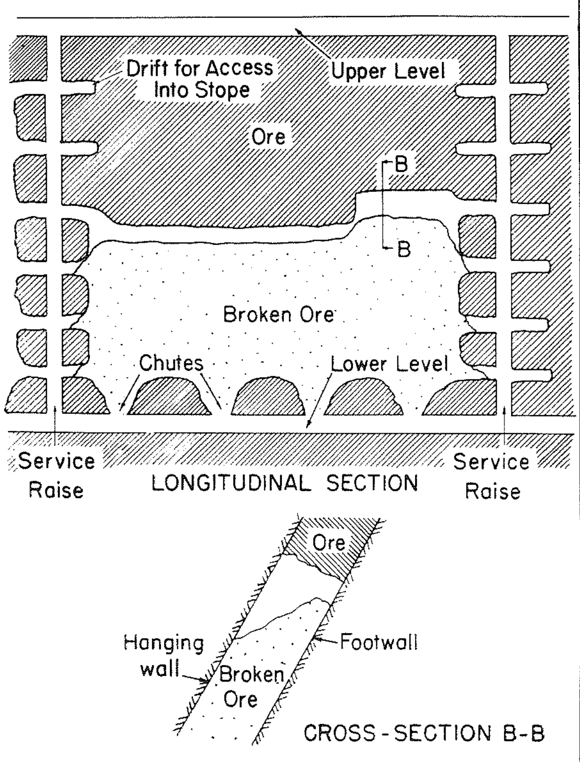


FIGURE 5-6.—Longitudinal and cross sections of a shrinkage stope.

ore must be drawn from the stope from time to time to provide working room. The remaining broken ore is left in the stope until the drilling and blasting is finished, after which all the remaining ore is drawn.

This system works well where ground conditions will permit its use, and it is good in steeply dipping veins. It is a fast cheap system of underground mining and, if done properly, will give good results.

Some disadvantages to this system are:

1. It is relatively dangerous because the ore may slip from underneath the working place.
2. The ore may oxidize when left in the stope; this may cause trouble in milling.
3. 60 percent of the broken ore is tied up in the stope.
4. Dilution by waste rock from a bad hanging wall may reduce the value per ton of the ore.
5. It is a difficult system to change once it has been started. Where the vein is not too wide, shrinkage stopes have been changed to stull stopes.

The shrinkage system normally does not require much development before mining can be started. As compared to other methods, it is regarded as a low-cost, high-production method. It is a popular system where conditions permit its use.

Resuing or Stripping.—The system known as resuing or stripping (Fig. 5-7) is generally used in narrow high-grade veins. The ore and waste are mined separately. The sequence of operations is as follows: The ore is first blasted or picked down on a clean floor and transported to the ore pass in a wheelbarrow or by a slusher, the floor is then pulled up, the waste blasted, the top of the wastepile leveled, the floor laid again, and the process repeated. This is a slow method, but it is an efficient system of keeping high-grade ore and waste separated. The waste being thrown down in the 'gob' supports the walls, therefore few stulls or rock bolts are needed, except in places where the valuable portion of the vein is wide. There a short raise may be driven in the hanging wall to supply waste. It may become necessary to remove some of the waste from the stope if the vein or paystreak is very narrow.

This system is popular with operators working in narrow high-grade veins where there is no mill on or near the property. Although costly, the ore produced from this system is usually free from waste, hence may be marketable as a direct shipping ore. The waste may contain sufficient minerals that it can be milled later at a profit, but it cannot be shipped at a profit, even though it is mixed with the higher-grade ore.

Cut-and-Fill Stopes.—In the cut-and-fill method, the space left by the removal of ore is filled with waste material, much of it from develop-

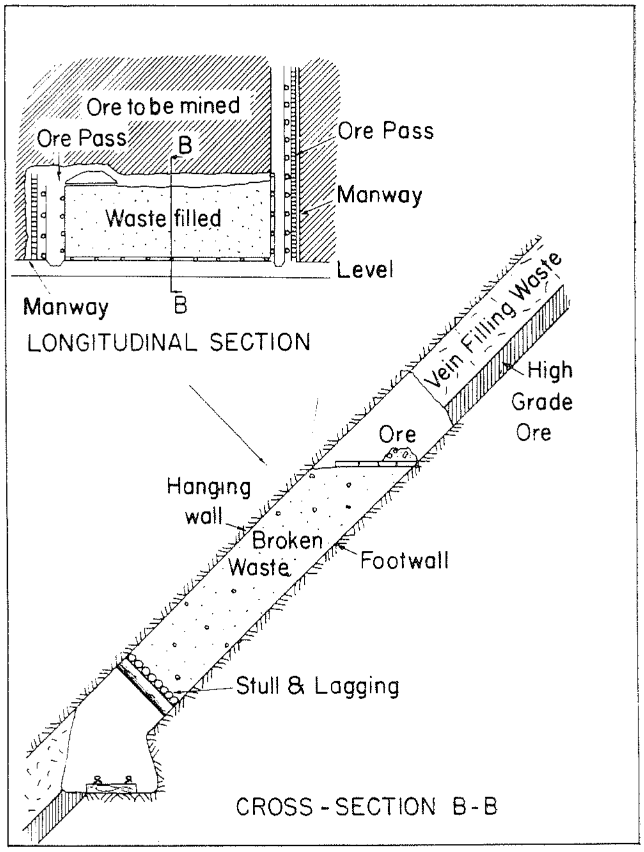


FIGURE 5-7.—Longitudinal and cross-sections illustrating the resuing or stripping system of mining.

ment work elsewhere in the mine. Not only does this waste material support the walls in the stope but also the top of the waste makes a convenient place from which to continue mining.

A typical cut-and-fill operation consists of driving raises at the ends of the block or driving one raise in the center of the block (Fig. 5-8). In one variation of this method, a pillar is left over the level for level protection, as shown in Figure 5-8. To start the stope, a sublevel or intermediate level is driven (right side of Fig. 5-8). Upon completion of the intermediate level from the raise to the extremity of the stope, another cut of ore the length of the stope is taken out directly above the sublevel. This cut is commonly 7 or 8 feet high. During this cutting (drilling and blasting), the ore is not removed except for necessary room. After the entire cut is completed, all of the ore is slushed out of the stope and down the raise. Fill material is introduced, usually from the level above, and the space is filled as shown in the upper left corner of Figure 5-8. The cycle is then repeated. If the ground is strong enough, it may be possible to take more than one cut across the stope before the broken ore is slushed out and waste fill introduced.

With the innovation of rock bolts and the hydraulic methods of transporting waste, the cut-and-fill method has become very popular. This

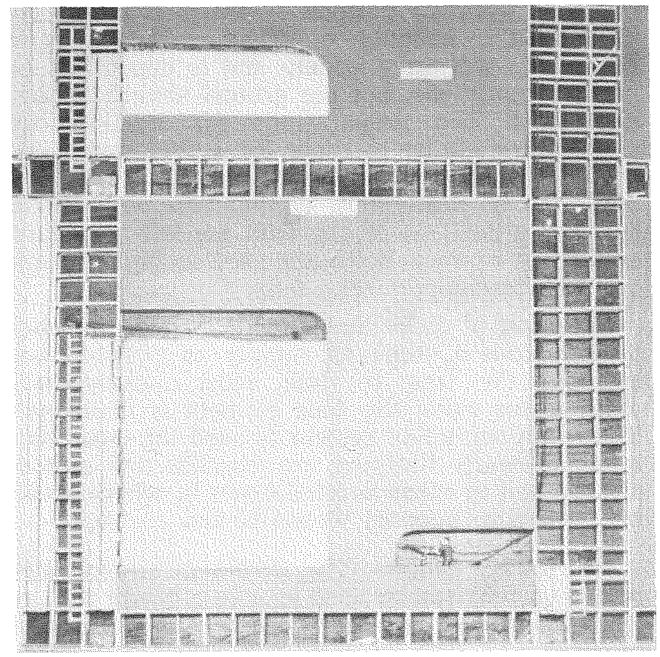


FIGURE 5-8.—Model of cut-and-fill stope.

method can be used in many places where previously only timber methods could have been used. The rock bolts give support to the walls and are substituted for stulls or other timber. The sand fill provides permanent support when it is emplaced in the mined-out stope. Slushers and modern rock drills speed the mining cycle greatly, therefore the ground is not left open for long before it can be supported; this reduces danger of caves.

Early-day cut-and-fill stopes were almost all filled with mine waste. If not enough fill was available, raises would be driven into the hanging wall for additional fill material. Ordinary mine waste for fill material has one bad feature when emplaced underground; there are many voids or open spaces in the fill because of the irregular packing of the different sizes of material. Air can filter through this fill, not only reducing the ventilation efficiency of the mine but also providing a potential fire hazard if there is timber or other combustible waste in the fill. These materials tend to oxidize and heat up in the air stream and may eventually burn, thereby causing an underground fire.

In recent years, mill tailings or other fine-size material has found widespread use as a stope fill. The advantages of this material are that the fine material packs tightly, reduces ventilation losses, and gives more efficient support; also the fine material can be transported through pipelines as a slurry, which simplifies the waste-handling problem. Fine fill and coarse mine waste can be dumped together into stopes because the fine material fills the voids of the coarse material, thereby giving a tight compact fill.

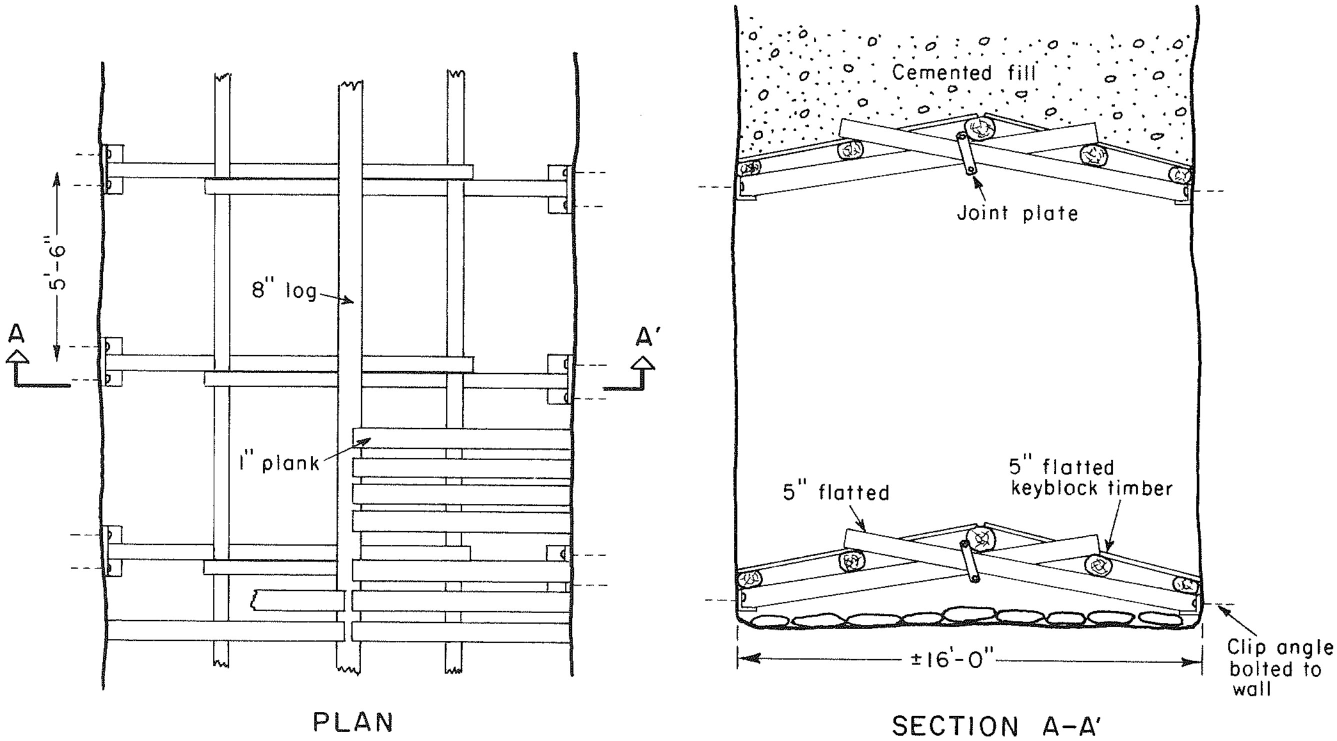


FIGURE 5-9.—Scissor set under cut and fill.

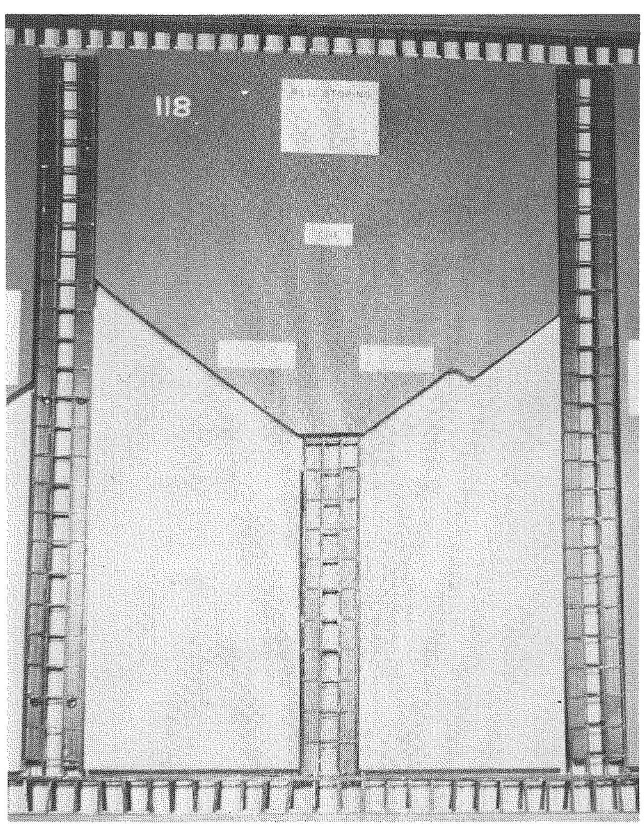


FIGURE 5-10.—Model of inclined cut-and-fill stope (rill stope).

Cut-and-fill stoping is normally regarded as a medium-rate production method, in comparison to all other methods. The cost per ton of ore produced is likewise in the medium range, that is, lower than for the timber method but higher than for the shrinkage or open-stope methods.

Recent developments in cemented sand fill and timber supports have been used by the International Nickel Co. of Canada (INCO) in developing an underhand method of mining in bad ground, especially in pillar recovery. In this process, the stope is started from the top, and as the ore is mined out, the space above is filled with cemented sand fill material. A scissor set, developed by INCO, is shown in Figure 5-9. In this method, hardened fill instead of a loose ore zone is overhead and safety in these stopes has been good. When underhand mining is resumed under a scissors mat, posts are not required for support. The absence of posts increases the efficiency of mucking equipment.

Rill Stope.—A variation of the cut-and-fill method is the rill method, often called the inclined cut-and-fill method (Fig. 5-10). The inclined workings are designed so that the broken ore will flow by gravity into a center raise, while the waste fill will flow into place by gravity from the end raises. The idea behind the development of this system was to eliminate the horizontal movement of ore from the stope and of waste into the stope by slushers or ore cars. The main objection to this method is that the men have very insecure footing, because of rocks sliding from underfoot,

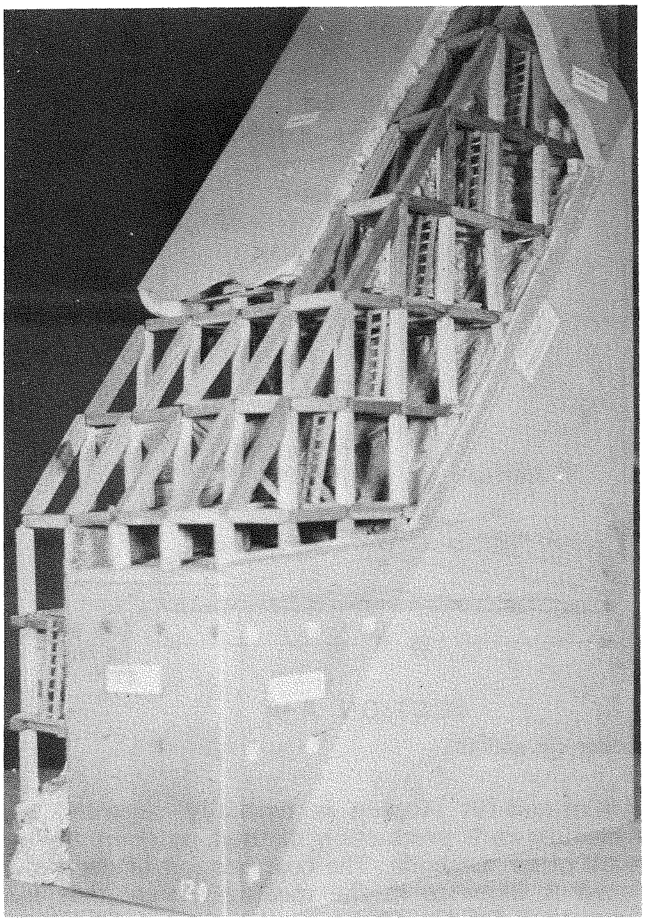


FIGURE 5-11.—Model of timbered stope.

and there is always a danger of being hit by rolling or sliding rocks from above. This method has only slight use in present-day mining operations.

Square-Set Timber Stope.—In the square-set method, stope faces or workings are advanced by successive stages. The excavation in one stage is only large enough for one or two sets of timber to be installed at a time. Timbers in each successive stage are joined together, usually by the framing on the ends, thus the timbers tend to support one another, and altogether this timber framework forms a continuous series of floors and compartments or sets. Figures 5-11 and 5-12 show this arrangement in models of actual stopes. By this method, all of the ground removed is replaced with a timber framework to temporarily support the back, face, and side of the excavations until they can be further supported by filling with waste rock. There are many variations of this method, but all use square-set timbers.

The square-set method is very flexible and can be used in wide or narrow veins, but it is expensive, so the ore must be relatively high grade. Where all other methods fail in ground control, the square-set method will usually give satisfactory results.

SUBLEVEL CAVING

The use of diesel-powered equipment underground and rubber-tired load-haul-dump vehicles instead of track-bound has led to a resurgence in sublevel caving in recent years. This method is applicable to ore bodies more than 10 feet wide, and because it is a high-production method, it is applicable in lower-grade ore bodies. It is most suitable to steeply dipping ore bodies where the capping waste rock and hanging wall cave readily but preferably do not break too finely, which may excessively dilute the ore. Although this method was originally developed for weak ore, use of long-hole drills permits its adaptation to ore that is strong enough to stand unsupported or with minimal support. If this system is used in wide veins, competent planning should be done by knowledgeable people so that ore recovery and efficiency are maximized. In vertical or nearly vertical veins 8 to 15 feet wide, it may be possible to develop a sublevel caving system if ore and waste conditions are amenable. The method can be used in wide veins of shallow dip, but the sublevel caving layout will differ from the one shown in Figure 5-13.

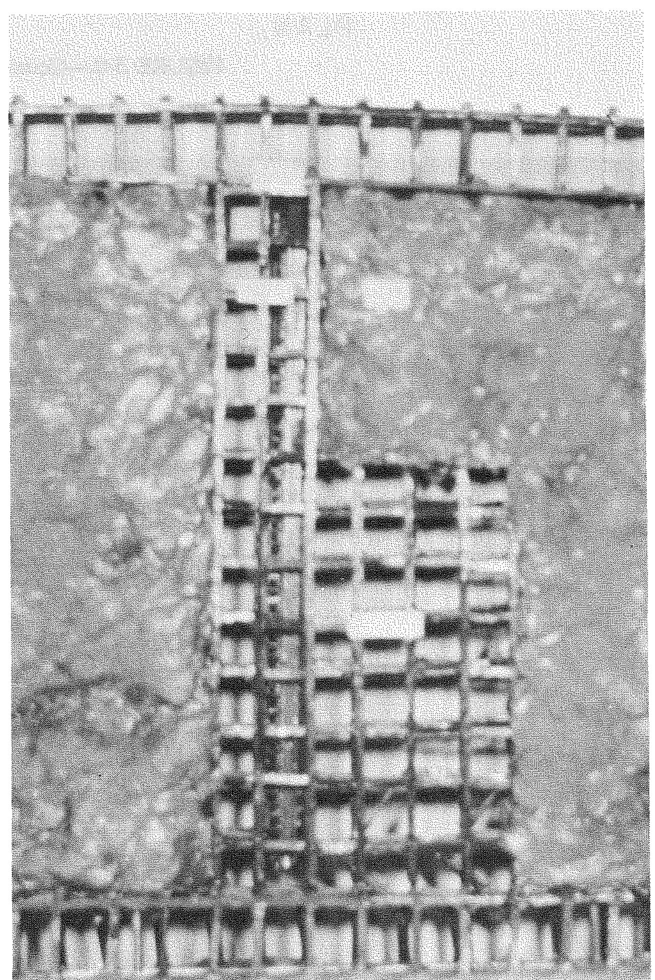


FIGURE 5-12.—Model of timbered stope.

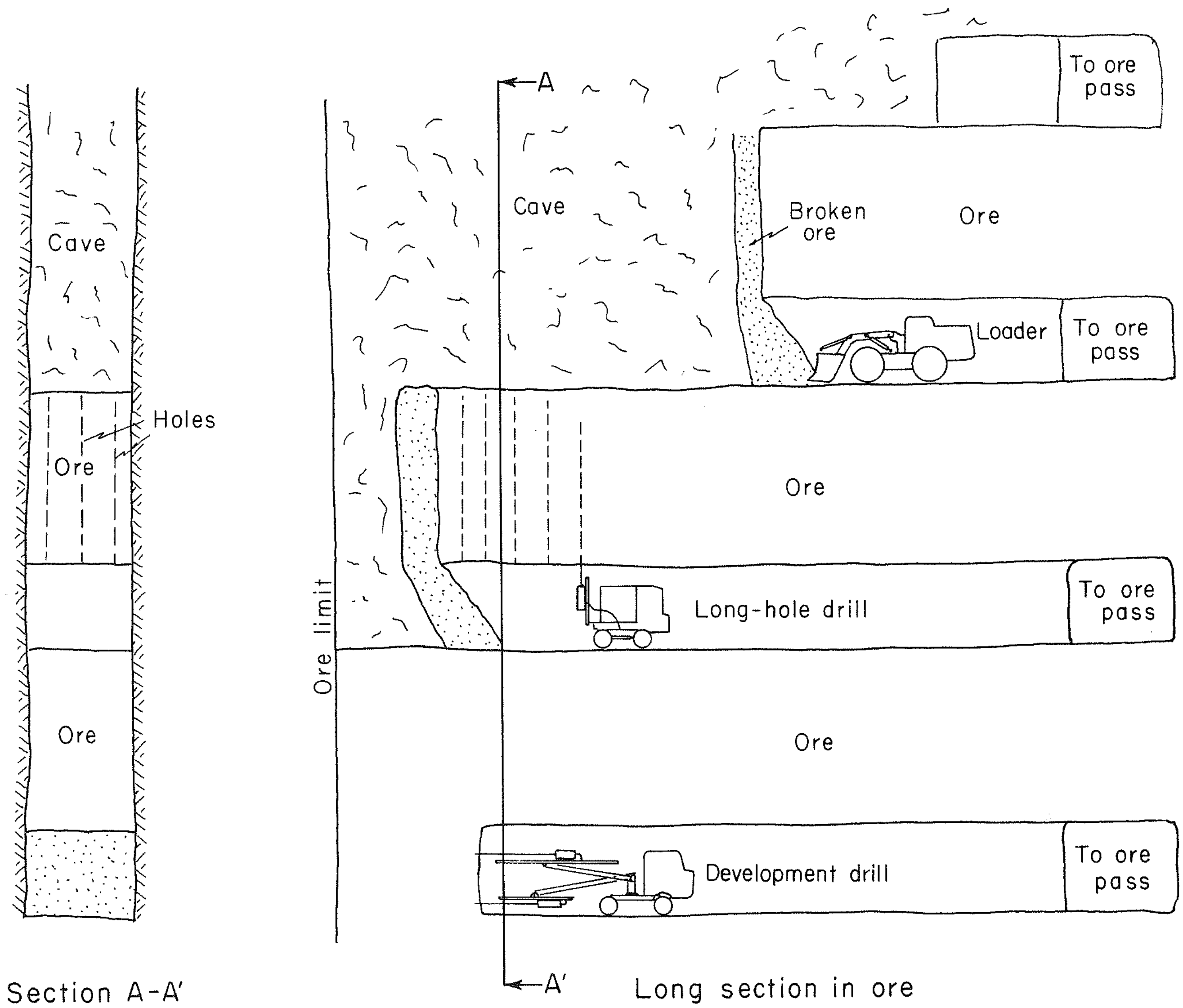


FIGURE 5-13.—Sketch of a sublevel caving operation in a vertical vein 10 to 15 feet wide.

Figure 5-13 is a sketch of a sublevel caving system used in a vertical vein 10 to 15 feet wide. As can be seen in this sketch, long holes are drilled in the ore and blasted against the waste. The broken ore lies between the waste and unbroken ore where it can be loaded and hauled away by a load-haul-dump unit. The ore runs down this funnel, and when waste appears, another round is blasted.

The level spacing depends on the way the broken ore flows and may range from 30 to 50 feet from bottom to bottom of development headings. The drill holes may be vertical or may tilt as much as 70° to the long section. This angle is governed by the way the ore draws down over the waste. There is always some waste dilution by this method, so it is used in lower-grade ores only if the mine is close to a mill where waste rock can be handled without excessive cost.

Because this method can be highly mechanized, much thought should be given to equipment selection. Load-haul-dump equipment has been used economically over tram distances as great as 1,000 feet. When diesel equipment is used underground, however, ventilation becomes very important. Diesel fumes can be poisonous unless adequately diluted with fresh air. Ventilation can no longer be neglected until conditions become bad, as it was with other methods. Plans must be made at the start of the operation to provide adequate and effective means of ventilating the mine.

The advantages of this system are that it can be used in a wide variety of ore bodies; it can be highly mechanized; and it is a flexible method, because it can be modified for unusual conditions or changed to some other method. On the other hand, there is always some dilution with this method, and ore can be lost. In most operations forced ventilation is necessary with this system.

SUMMARY

Table 5-1 has been prepared to summarize the features of the various mining methods. One should check to see whether perhaps a lower-cost method might be suitable for his mine.

This chart is not complete; it leaves out most of the underground caving systems. One of the requirements for most of these systems is that the ore body must be of considerable size. To plan and institute a caving system efficiently, competent technical help must be sought.

TABLE 5-1.—Comparison Chart of Mining Methods

	MINING METHOD	Comparative cost per ton of ore produced	Tonnage required to institute method	Production in tons per man shift	Grade of ore (usual conditions)	Can systems be easily changed to another?	Development necessary before mining	Is much support required?	Dip of vein	Safety record of method	Recovery and selectivity of method
Open stopes	Gophering	High	Low	Low	High	Yes	Low	No	Any way	Medium	Good
Open stopes	Glory hole	Low	Large	High	Low	No	Low	No	Any way	Poor	Poor
Open stopes	Stull	Medium	Low	Medium	Medium	Yes	Low	Medium	Steep	Medium	Good
Open stopes	Pillar	Low	Medium large	Medium high	Low	No?	Low	No	Flat	Good	Medium
Cut and fill	Resuing	High	Low	Low	High	No	Low	No	Steep	Medium	Good
Cut and fill	Horizontal cut and fill	Medium	Medium	Medium	Medium	Yes	Medium	No	Medium steep	Medium	Good
Cut and fill	Inclined cut and fill (rill)	Medium	Medium	Medium low	Medium	Yes	Medium	No	Steep	Poor	Poor
Cut and fill	Underhand cut and fill	Medium	Medium	Medium	Medium	Yes	Medium	No	Steep	Good	Good
Shrinkage		Medium low	Medium large	Medium high	Low medium	No	Medium high	No	Steep	Poor	Medium
Timber (square set)		High	Low	Low medium	High	Yes	Medium	Yes	Any way	Medium	Good
Sublevel caving		Low	Medium	High	Low	Medium	High	No	Steep	Good	Poor
Open pit		Low	Large	High	Low	No	Low	No	Any way	Good	Good

MINE LAYOUT

FACTORS THAT INFLUENCE MINE LAYOUT

The proper layout of a mine is necessary for the maximum recovery of ore at the lowest cost per unit. Stating this in another way, layout influences the profit that can be derived from ore. What do we mean by the term Mine Layout? Mine layout deals with the arrangement of the physical parts of the mine — the shafts, drifts, raises, stopes, surface plant, pumping plant, and other structures and equipment necessary to produce the mineral product. Planning the mine layout consists not only of selecting the type and arrangement of the various mine openings but also the scheduling of the sequence of operations so that the mineral product can be produced efficiently under the physical conditions dictated by the ore body. In all of this planning, the problem of providing manpower for all of the operations must be considered.

Mine layout is an important responsibility of mine management. There are mines that could have been developed more cheaply by adits rather than shafts; proper planning would have saved the expense of a costly shaft. Level spacing influences mining costs. In some mines, levels are spaced at certain intervals, such as 100 feet, because it has been that way in the past or because many mines use this 100-foot spacing. True, in some mines, 100-foot level spacing may be optimum, but in others perhaps smaller or greater level intervals may permit more efficient operation. Levels cost money, yet they are needed for ore recovery. One responsibility of the mine planner is to determine the proper level spacing for efficient operation.

Several points to be kept in mind when planning the mine layout are:

1. Do everything possible to speed up the mining process. (More production per man shift means less cost per ton.)
2. Keep material and ore handling to a minimum.

3. Keep plans flexible so that they can be readily changed if adverse conditions are encountered.
4. Plan the flow of ore and supplies so they move to their destination in the shortest time with the minimum number of transfers and stops.
5. Keep the investment in equipment to a minimum.
6. Promote effective use of labor by eliminating unnecessary steps. Also do not overlook the comfort and health of the employees. Morale is an important factor in any mining operation.
7. From the inception of any underground or surface mining plans, give proper consideration to the rehabilitation and ecological problems in all surface planning. In most states, mining plans must be approved by a state agency before mining actually begins. Potential air and water pollution problems must be resolved before a mining permit will be granted.

Unfortunately, the person responsible for mine layout can seldom choose the best location for the mine. Nature not only chooses the location of the mineral deposit, but dictates the physical environment as well. After the deposit has been found and prospected, the planner must try to obtain sufficient information to help him with his task of mine design.

TOPOGRAPHIC FEATURES OF THE AREA

Topographic maps of most areas in the United States have been prepared by the U. S. Geological Survey. In the western United States, much of the mountainous area is administered by the U. S. Forest Service, and other areas are serviced by the U. S. Bureau of Land Management. Each of these agencies has accurate maps for sale at nominal cost, and the air photos from which the maps were constructed are also available at reasonable cost. A good place to seek information on the availability of maps is the State Geological Survey or equivalent agency. If it is not the distributor of the needed maps, the agency will know where they can be obtained.

The surface features and location of the deposit most commonly dictate the type of development openings required for the prospect or small mine. If the deposit is in a steep mountainous country, adits may be most economical and convenient for development. If the deposit is in an area that is relatively flat, a shaft must be sunk. The location of the surface plant, buildings, roads, and mill must be considered in relation to the main development opening into the mine. If an adit can be started in any one of several locations without affecting the underground mining, then the most favorable location for the surface plant should be a governing factor. Cutting away dirt or rock or filling low places to make room for a surface plant should be avoided, if possible, or reduced to a minimum.

Other points pertaining to topography that one should consider:

(1) Will spring runoff water or cloudburst water run into or interfere with the operation of the mine through the main development opening?
(2) Are the exposed development openings reasonably protected from snowslides, landslides, or rolling rocks?
(3) Does the surface area have protection from strong winds?
(4) Is there sufficient dump room?
(5) Is the area accessible?
(6) Can the development work, dumps, road, tailings piles, and other surface disturbances be hidden from the view of the general public? Many persons feel that mine endeavors impair the landscape, and they are unsympathetic to mining problems. Therefore, the possibility of selecting canyons or hillsides away from towns or main highways for the surface facilities should be given considerable thought.

Although an ideal location cannot be found for every deposit, it may be possible to minimize some of these problems. The author recalls one mine developed by an adit that started on the windy crest of a hill. The strong wind would occasionally destroy some of the surface equipment, and during the winter it was frequently very cold. If the mouth of the adit had been placed around the hillside a few hundred feet, much of this wind damage could have been avoided. Another example was a shaft that was sunk in a dry gully. One summer a cloudburst flooded the mine. Locating the shaft a few feet either way would have avoided this trouble, yet would not have interfered much with the rest of the surface plant.

Shape, Size, and Grade of the Deposit.—The exact shape, size, and grade of the deposit cannot be determined until the mine is completely worked out, yet planning must be done for maximum recovery. To determine the exact shape, size, and grade of the ore body in advance is exorbitantly expensive, but some well-directed prospecting or drill holes may give the geologist enough information to predict the approximate shape, size, and grade of the ore body. The educated guess is better than blind planning.

If the extent of the deposit is small, but the ore is high grade, then a complete ore recovery system must be devised. On the other hand, if the deposit is large but low grade, a high-production low-cost method must be employed. A large deposit of ore will repay a large capital expenditure for development and mining equipment; a small deposit normally dictates minimum equipment, development, and expense for ore production.

Position of the Deposit.—The position of the deposit in relation to the surface of the earth dictates whether an open-pit method is feasible. If the size is sufficient and the deposit is near the surface, open-pit methods should be considered. The position or attitude of the ore body may dictate the types of development openings. A flat-dipping ore body, say 25° dip, may be much more conveniently developed by an inclined shaft than by a vertical shaft. The dip of the vein affects level spacing. A flat dip usually requires closer spacing of levels in elevation than does a steep dip, because the distance along the vein is greater for a given difference in elevation.

Geological Environment.—The geological environment is extremely important in mine layout. In some ore deposits, the ore and wall rock are soft and will not stand unsupported, but 20 to 50 feet from the vein the wall rock is firm and may stand either untimbered or supported with rock bolts. In a situation such as this, development openings in the vein zones require constant repairing whereas the openings in the wall rock away from the vein require little maintenance. As a rule, however, in most prospects and mines of small production, it is a better policy to stay with the ore with development headings even though the maintenance cost is greater.

If the deposit is in sedimentary rocks, the layered sequence may be an advantage. For example, shale, limestone, and quartzite beds may lie in close proximity to one another. Therefore, it may be advantageous to drive the development headings in one of these beds, then crosscut over to the ore. The author recalls one prospector who drove an inclined shaft in very hard quartzite to prospect for a lead showing reported in an old abandoned mine at the 200-foot level. If he had moved his shaft up the hill about 50 feet, he could have driven it in softer shale. True, he may have had heavier ground, but he could have driven it must faster and more easily, and he would have reached his destination much sooner.

Faults are complicating factors in mine layout. They may not be found until the development openings intersect them, but if known, they must be considered in mine layout or in future development.

Rock Types in Ore and Wall Rocks.—Rock types and ore minerals are a part of the geological environment, but because they influence the choice of the mining method so much, they will be discussed separately. The following strength classification is used here:

Strong or self supporting: That is, rock or ore that will stand over 50-foot spans in any direction without support.

Fairly strong: That is, rock or ore that will stand over a span of 20 to 50 feet without support.

Weak: Rock or ore that will stand without support over a span of only a few feet.

The strength of the wall rocks and ore dictate the mining method, which in turn affects the value of the ore body. Shrinkage, room-and-pillar, and most open stoping methods can be used only in ore bodies where the walls and ore are strong or at least fairly strong. As these are the low-cost methods, the ore does not have to be high in value. Cut-and-fill ore resuing may be used in fairly strong to weak ore bodies and walls, provided the span does not become so great as to result in failure, and provided further that temporary support can be obtained by use of rock bolts, stulls, or other timber. As this method is more costly, the ore must be higher grade than for the methods previously mentioned. Timber methods are commonly the most expensive, so the ore must be high grade, but timber methods can be used where the ore and walls are weak. If the ore body is large enough, but both the walls and ore are weak, and the ore is not high grade, caving should be considered for deeply buried bodies; if near the surface, open-pit mining may be the best method.

Where the ore is fairly strong and the walls are weak, the cut-and-fill method may be employed, provided the walls can be temporarily supported until fill is introduced for permanent support. In this type of ore, sublevel caving could be an efficient method of mining. If the walls are strong and the ore is weak, a system of caving may be employed, or a combination of other methods can take advantage of this unusual situation.

Conclusion.—All of the natural factors mentioned should be considered when planning the mine layout, because they govern the conditions. Only by accepting these conditions and planning to either bypass, compensate for, or take advantage of these conditions can we efficiently and effectively mine the ore body. As we shall see, many man-made factors also enter into and influence the problems in mine layout.

LOCATION OF DEVELOPMENT HEADINGS

The fundamental purposes of development openings are to determine the size, shape, limits, value, and mineralogy of the ore and the physical characteristics of the wall rock and to prepare the deposit for mining. Knowing the complete physical and economic features of an ore body is most desirable, but obtaining this knowledge at any one time is impracticable, because the entire mineral deposit cannot be prepared for mining before actual mining begins. Moreover, economic necessity usually dictates obtaining returns from the operation before it is fully developed.

METHODS OF OPENING A DEPOSIT

There is one cardinal rule that the small-mine operator should follow: Stay with the ore or vein structure until its continuity is proved. In the selection of an opening to the mineral deposit, this rule should be one of the determining factors.

An ore body can do some erratic things in a very short distance, and the sooner an operator can learn its behavior and peculiarities the better off he will be. Disregarding this rule has caused much needless work. Many hillsides in mining areas have large dumps that show that a long crosscut adit was driven to intersect an ore vein at depth. The vein was exposed on the surface in a few scattered outcrops, but was not found at depth, or it was too low grade to mine, or funds ran out before the project was completed. If the work was not completed, then the answer to the question whether a valuable prospect exists is still unknown.

Elsewhere in the west, mill foundations and rotting mill buildings at small prospects where very little, if any, ore was milled bear mute evidence of the lack of development in ore. The feeling of an over-enthusiastic promoter is that if he had a mill to handle the low-grade ore a large profit could be made. Money is raised and a mill is built to mill ore exposed only by a few surface showings of a vein. If the ore body does not persist at depth, the whole project is a failure. Much money, effort, and time can be wasted by the lack of a proper development program.

If money is wisely spent in a development program, and ore is exposed, more money can usually be raised to further develop the property, or, because of a good ore showing, the property may become salable to a larger mining company. Profit is more assured from a well-planned development program than it would be from haphazard work.

Following the ore has several advantages: (1) The ore body is being outlined and prepared for mining; (2) removing and saving the ore will defray some of the cost of development; (3) much ore is softer and easier to remove than the country rock; and (4) any irregularities in the ore body such as faults, pinches, swells, change of enrichment, and other unusual features are noted immediately. The main disadvantages of following the ore are: (1) Supporting the excavation may be a problem because the ore may be heavier, softer, or more fractured than the country rock; and (2) the strike of the vein may be irregular or curved. These factors are disadvantages because they hamper efficient service and ore hauling in the mining areas. In some large mines, service and ore handling are so important that most of the development openings, such as levels and transfers, are driven in the country rock. It must be remembered, however, that the limits of the ore bodies in these mines are usually already well defined by geologic inference or by drilling, whereas the limit of the ore body in a prospect is unknown.

Another rule of thumb of prospecting is to drift wherever possible. The advantages of drifting are that it is cheaper than shaft sinking, and it provides a natural drain for water. Less equipment is required for drifts than for shafts.

Usually the choice of opening for a deposit must be made by the operator; no established rules will fulfill all conditions. As an example, a vein can be traced for a long distance but surface work exposes only one shoot of rich ore. There are two choices, sinking on the ore or moving down the hill and drifting along the vein. Other considerations are: (1) Accessibility of the opening by roads; (2) water conditions; (3) amount of cover or depth obtained on the vein by a drift; and (4) length of the drift. A drift, in a situation like this, would prospect the vein and perhaps encounter some unknown ore shoots; on the other hand, shipping ore could be mined while sinking a shaft on the rich ore.

A long crosscut should be discouraged in the initial stages of opening a mine, because of the expense involved. It is true a crosscut does prospect the walls for parallel veins but in many places a trench cut on the surface by a bulldozer or a backhoe will give the same information at a much lower cost.

In regions where the topography does not permit a drift or crosscut, a shaft must be sunk. As many veins dip other than vertical, the question arises whether to sink an inclined shaft in the ore

TABLE 5-2.—Comparison of vertical and inclined shafts.

Vertical	Inclined
Safety dogs on cages give good protection against accidental uncontrolled fall.	Dogs cannot be used without guides. Safety devices unsatisfactory or complicated and expensive.
Requires less time and distance to reach a given elevation.	Requires more distance to reach a given elevation.
Rope wear due to abrasion is moderate to low.	Rope wear is high and rope requires much maintenance.
No rope rollers needed.	Rope roller maintenance high.
Skip and cage maintenance low.	Skip and cage maintenance high.
Requires large hoist and high horsepower to lift heavy loads rapidly.	Higher horsepower to equal hoisting rate of vertical shaft. Needs more rope.
If vein is vertical, crosscuts to vein no problems. If vein dips away from shaft, length of crosscuts to vein increases with depth.	If a dip of shaft parallels the vein, crosscuts to vein no problem.
In sinking, vertical mechanical shaft muckers have been developed to give good efficiency. Other recent shaft-sinking techniques have resulted in increased rates for sinking.	In sinking, mucking still presents a problem in shafts steeper than 20° in dip. Some recent machines have given good results in steeply dipping inclined shafts, however.

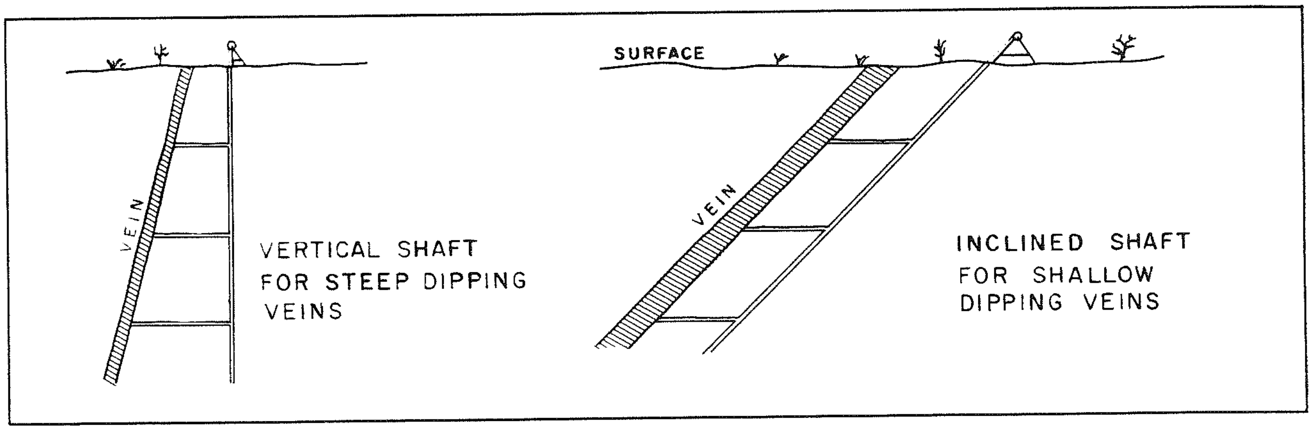


FIGURE 5-14.—Sketch showing vertical and inclined shaft layouts.

or a vertical shaft in one of the walls. Consideration of the first rule of prospecting (stay with the ore) will decide in favor of the inclined shaft. A few arguments against inclined shafts in the ore are: (1) they are slow to construct and inefficient; (2) they may be irregular because of an irregular ore body; and (3) ore in pillars must be left alongside the shaft for support. If a large ore body is found at depth, however, a vertical shaft or a straight inclined shaft in the footwall can be sunk or can be raised from the level below. The original prospect shaft can be used as a raise in mining operation, as a ventilation circuit, or as a secondary escapeway.

SHAFTS

If a mine proves valuable, in all likelihood a shaft must be sunk. When a mine is in its infancy, plans must be made to sink a shaft to handle a large production of ore. The location, size, and arrangement of a shaft for large-scale production must be given considerable thought because production of the mine depends on the capacity of the shaft. Unfortunately there is no standard rule for the proper location of the shaft with respect to the ore body. The ore body should dictate the type and location of the shaft, except that it be in the footwall preferably. Below are discussed some of the different shaft layouts.

Inclined vs. Vertical Shaft.—Figure 5-14 illustrates a vertical shaft and an inclined shaft servicing two differently dipping veins. Table 5-2 compares the advantages and disadvantages of these two shafts. The decision as to whether to use a vertical or an inclined shaft usually depends upon the dip of the ore body. For dips less than about 60°, the inclined shaft is used because at depth the length of crosscuts from a vertical shaft to the ore body becomes excessive.

POSITION OF SHAFT WITH RESPECT TO WALLS OF ORE BODY

Inclined Shafts. — An inclined shaft may be positioned in the footwall, the hanging wall, or the ore. In a prospect, the vein should be followed, principally for the purpose of prospecting the vein. After the ore has been proved, however, locating the shaft in one of the walls may be more desirable. The hanging wall is least desirable, because possible movement of the hanging wall after the ore body is mined may cause damage to any mine opening within it. Consequently, maintenance costs in a hanging-wall shaft may become excessive. Too, the mechanics of ore dumping from the level development openings favor a footwall location. Because of these factors, and unless other unusual factors enter in, the most desirable location of an inclined shaft is in the footwall.

Vertical Shafts.—There are several possible locations of a vertical shaft with respect to a dipping ore body. Figure 5-15 shows three possible layouts for the same ore body. The one entirely in the hanging wall requires long crosscuts to reach the ore zones at the start of mining when pressure is on for production to help defray operating expenses, thus consuming both money and time. Furthermore, if the hanging wall moves during or after mining, the shaft may be damaged or lost.

The layout in which the shaft is started in the hanging wall and passes through the vein into the footwall is favored by some mine operators. The big advantage of this layout is that the crosscuts to the vein are not excessively long. Not only are the disadvantages similar to those of the shaft in the hanging wall, however, but usually a pillar of ore must be left to protect the shaft

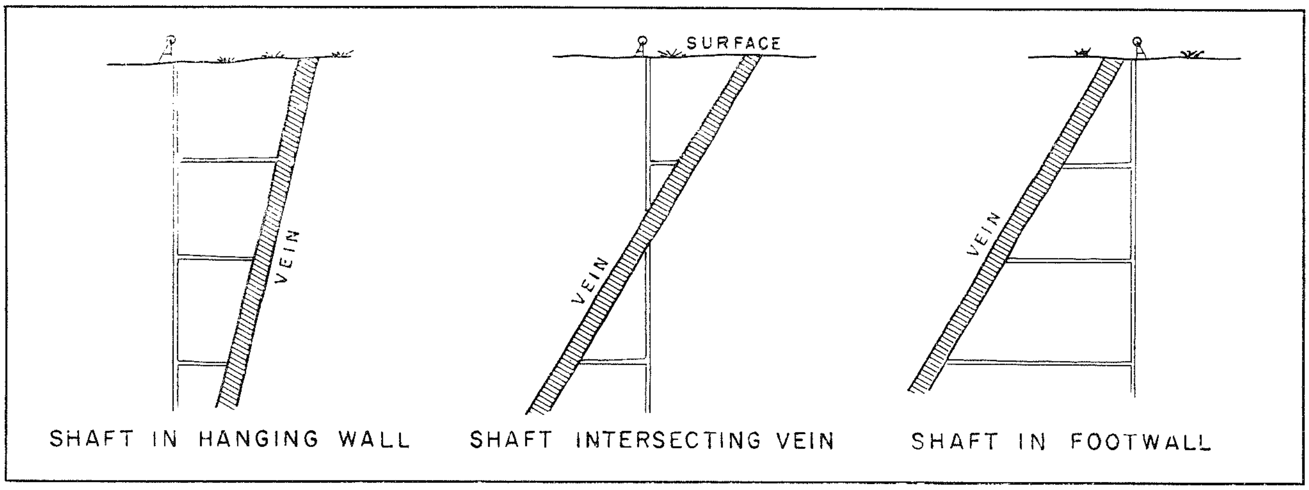


FIGURE 5-15.—Sketch showing three positions of a vertical shaft in relation to vein.

where it crosses the vein. Also, if the vein is composed of weak ore, ground support of the shaft in this area may be difficult.

The layout in which the shaft is entirely in the footwall does not have the problems of ground support and ground movement that may affect the other layouts. The disadvantage of this layout is that as the shaft gets deeper, the crosscuts from the shaft to the ore become progressively longer, thus increasing development and haulage costs.

Surface topography must be considered also when selecting a shaft site, but it should not be the controlling factor. Leveling or preparing a shaft site better situated with respect to the ore body may save considerable money over the life of the operation, even though the site preparation is more expensive initially. This applies to a mine with known ore reserves, not necessarily to prospects.

Recent developments in the science of rock mechanics show that the location of a shaft with regard to the ore body must be given detailed study. Stresses build up around openings and can extend over a large distance. These stresses can affect the stability of a shaft. For example, even though a shaft is located in the footwall of a steeply dipping deposit, a caving method of mining the ore may cause ground movement that can destroy the shaft. Therefore, if the shaft is too close to the deposit, a method of mining must be chosen that will minimize wall movement and wall stress build-up. In such a situation, the more expensive cut-and-fill method of mining may be necessary to protect the shaft although the ore body may be amenable to the low-cost high-production method of sublevel caving.

LOCATION OF LEVELS

Level spacing in a mine affects the ultimate cost of mining an ore body. Levels in a mine cost money to drive, equip, and maintain; therefore, the minimum number of levels necessary to mine the ore efficiently should give lowest cost per ton of ore mined. Improper level spacing may be one of the contributory factors to high production costs.

The level spacing frequently chosen is some multiple of 50 feet but usually less than 200 feet. The only reason given for this choice is because it has always been this way, or other mines use this interval. Although these level spacings may be the most economical in some mines, it does not necessarily follow that they are economical under all conditions. In some mines, level spacings have been increased to as much as 1,000 feet, but for most mines this is too great. What then should control level spacing? Probably the most important controlling factors are ore predictability at depth, the characteristics of the ore and wall rock, and the economic factors, which may be further subdivided into:

a. Time required to open a level.
b. Repair and maintenance costs of a level.
c. Production requirements of the mine.
d. Development costs.
e. Mining costs.
f. Recovery of ore.
g. Safety of operation.
h. Human element involved.

Geologic Factors. — To choose proper level spacing we must be able to predict with reasonable certainty the continuity of ore at depth. Therefore, before making too many plans, it is wise to prospect by long-hole drilling, as well as to gather and study all geological data that have a bearing on the behavior of the veins at depth.

The structure of the vein and strength of the ore and wall rock usually determine the choice of the mining method, which in turn affects the choice of level spacing. If the ore and wall rocks are hard, firm, and will stand unsupported over large spans, the levels can be spaced at greater distances. If the ore is abrasive and causes the ore passes to wear out before the stope is mined out, however, the cost of repair and maintenance of the passes may offset the money saved by greater level spacing. In ore deposits with flat dips, the length of slusher haul affects the cost of moving ore and would be an important factor in level spacing.

Other Factors.—The time required to complete development work is important in small mines because the operator is usually working with small capital, and there is a need for getting into production quickly. Thus, economic pressure may demand the opening of another producing level at a fairly shallow depth. In large mines, more time and money is commonly available for deeper level development, hence the economic pressure to put a level into production is not as great.

The length of time that a level is to be maintained may be a factor. In heavy ground, a level may stay open for only a year or less, after which the maintenance costs to keep it open increase greatly. Therefore, level spacing such that the ore above any one level can be mined before maintenance costs become burdensome is justified.

If a level is to produce 5,000 tons of ore per day, large haulage equipment and a good track or roadway system must be used. If a level is to produce only 50 tons of ore per day, then much smaller, cheaper, and fewer units of equipment can be used. Therefore, cost of capital equipment on levels is an influencing factor on level development.

Development costs affecting level spacing are the costs of drifting, crosscutting, and raising. Direct stope-mining costs may also be influenced by level spacing. As a rule, the greater the level spacing, the less efficient are the miners in the stopes, unless their access and supply ways are convenient.

The recovery of ore may also be dependent on level spacing. For example, the levels may be so far apart that caving starts in the stopes before they are mined out. Some of the ore may be lost. If it is decided to get all of the ore, the cave must be 'caught up', thereby adding to the mining cost. If pillars are left, and it is desired to recover pillars, ease of recovery may be affected by the spacing of the levels.

Of paramount importance in all mining is safety of operations, and the reactions of the men involved in mining. Safety may not be connected directly to level spacing, but people charged with safe practices have found that tired men are more accident prone than fresh men. Climbing long raises to a working place is tiring and demoralizing to most men. Except in unusual cases, work is less efficient in isolated places that must be reached by a long climb. Supervision, also, is likely to be less effective in these out of the way places, thereby resulting in lower production.

How can all of these factors be considered when studying the proper level spacing for any set of conditions? To illustrate, a hypothetical problem is worked out.

Level spacing estimations:

ASSUMPTIONS

Width of ore body	Average 6 feet
System of mining	Cut and fill
Mineralization	Fairly constant
Length of ore shoot	800 feet
Depth of ore shoot	Unknown, but drilling indicates that it extends at least 600 feet below present level.
Dip of ore body	Vertical
Density of ore in place	10 cu. ft./ton
Production rate	200 tons/day
Drift length per level	1,200 feet
Raises required	9

Development is far enough ahead to allow proper spacing; same type and kind of equipment on every level.

KNOWN OR ESTIMATED COSTS (1975)

Cost of shaft sinking	$400/ft.
Cost of level driving	Average $100/ft.
Cost of raising	
to 100 feet	$80/ft. includes ore pass
100 to 200 feet	$90/ft.
200 to 300 feet	$100/ft.
Cost of shaft station and pockets	$120,000
Equipment cost per level	$100,000

Variable costs dependent on different factors.
Repair cost to levels
to 1 year .... $80/working day
1 to 3 years .... $120/working day
3 to 5 years .... $250/working day
(One year consists of 260 working days.)
Ore pass maintenance costs .... See Fig. 5-16.*
or
Increased cost of safety and loss
in efficiency, $/ton .... See Fig. 5-17.*

Quantity of ore per foot vertical depth

$$\frac{6 \times 1 \times 800}{10} \quad \frac{6 \text{ ft. wide} \times 1 \text{ ft. depth} \times 800 \text{ ft. long}}{10 \text{ cu. ft/ton in place}} = 480 \text{ tons of ore/vertical ft.}$$

Trial and error method of calculation:

Assumptions: (1) Assume only 85 percent of ore is recovered because of level and raise pillars.
(2) This analysis does not include direct mining costs, only the costs shown in Figures 5-16 and 5-17, which are affected by level spacing.
(3) Life of level is calculated on rate of 200 tons/day and if all ore is recovered between levels, but full 200 ton/day production on any level will probably not be realized when starting or stopping.

LEVEL SPACING OF 100 FEET:

	Cost	Ore recovered
Shaft station	$120,000	480×100×0.85= 40,800 tons
Level development 1,200×100	$120,000	
Raises 9×($80×100 ft.)	$ 72,000	
Repair cost: est. life $\frac{480 \text{ tons} \times 100 \text{ ft. spacing}}{200 \text{ tons/day prod.}} = 240$		
240 days × $80/day	$ 19,200	
Ore pass maintenance cost	0	
Efficiency loss	0	
Equipment cost/level	$100,000	
Shaft cost $400 × 100 ft.	$ 40,000	
Total	$471,200	

Total development cost/100 ft. level $\frac{\$471{,}200}{40{,}800} = \$11.55/\text{ton}$

* The three assumptions made in this problem, level-repair cost, ore-pass maintenance cost, and the efficiency of work for different level spacing are most difficult to estimate or calculate. Many operators do not keep enough records to determine these figures. The author has kept sketch records from time spent in operations, and from this meager evidence Figures 5-16, 5-17, and 5-18 were prepared. These curves will differ for each mine, but they have been checked for a few operations, and the resultant curves seem to have slopes as shown in these figures.

LEVEL SPACINGS OF 150, 200, 250, and 300 FEET

A similar calculation for 150-foot spacing would have the added costs of 50 feet of raise at $90/ft; repair cost of $80/day for an additional 120 days; ore-pass maintenance cost of $3,672 (from Fig. 5-16); a decreased-efficiency charge of $18,360 (from Fig. 5-17); and an additional 50 ft. of shaft at $400/ft. for a total of about $563,692 against 61,200 tons of ore, or $9.20/ton. Continuing similar calculations for level spacings of 200, 250, and 300 ft. would give results as tabulated below.

	100 ft.	150 ft.	200 ft.	250 ft.	300 ft.
Cost: $/ton	$11.55	$9.20	$8.22	$8.16	$8.45

From the above, it can be seen that the most economical spacing should be about 250 feet, because the cost per ton begins to rise if this

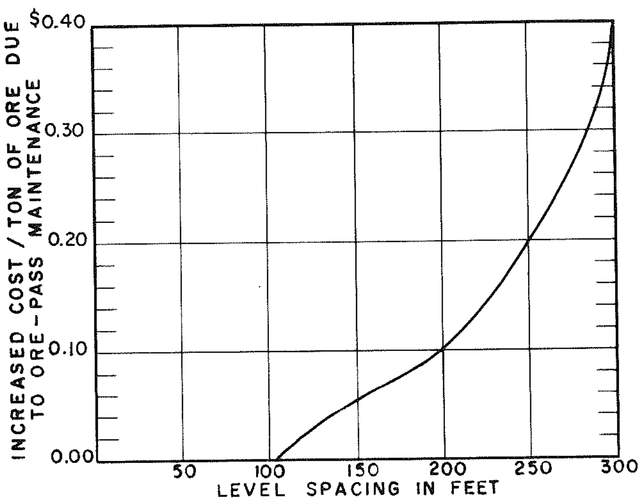


FIGURE 5-16.—Ore pass maintenance cost as affected by level spacing.

spacing is exceeded, but any spacing between 200 and 300 ft. would probably be satisfactory under these assumed conditions. Of course, the total cost of mining a ton of ore would be greater, because the overall mining and overhead costs were not included in this figure. Such costs should, however, be constant for any level spacing.

Most calculations are more involved than this simple example, because more information is available for a mine that is actually operating. To help with ore predictions at depth, it is customary to take past ore calculations and past operating figures and project these to lower levels. With this help, the level-spacing calculations should be more reliable and accurate.

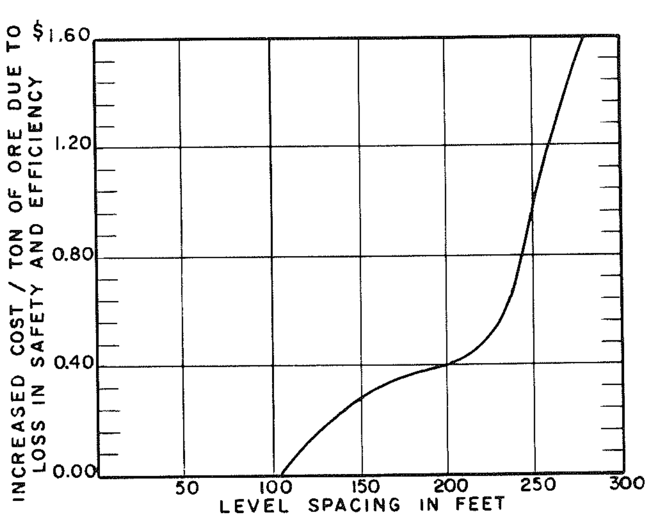


FIGURE 5-17.—Increased cost of safety and loss in efficiency due to increased level spacing.

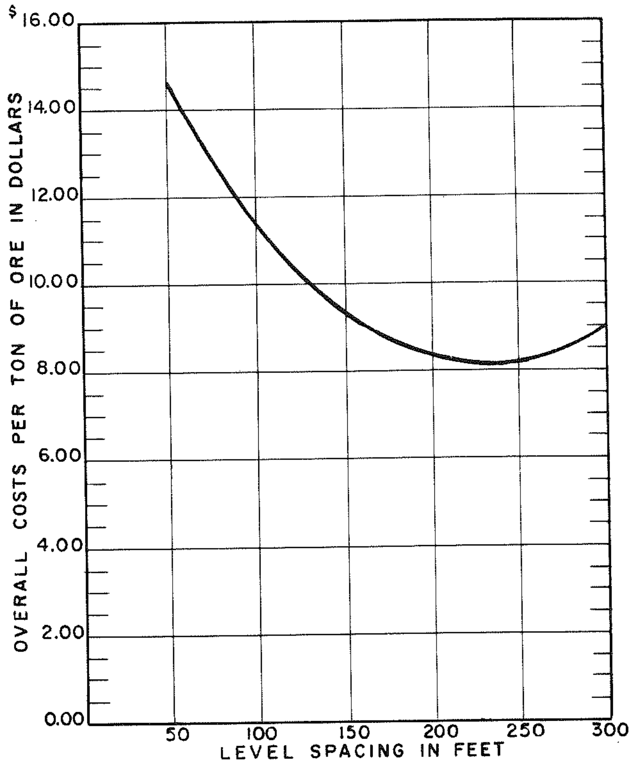


FIGURE 5-18.—Level spacing and its effects on the production cost per ton of ore.

POSITION OF DRIFTS WITH RESPECT TO VEIN

The position of the drift with respect to the vein is important because proper positioning can eliminate much later work and trouble when the ore is mined. If the vein dips steeply and is wide, better practice dictates that the drift should be carried on the footwall side of the ore body (Fig. 5-19c). This is true because the ore when broken in stoping operations tends to run down the footwall; hence, it can be more easily accumulated for loading into cars in the drift below.

Figure 5-19 shows three positions of a drift on a narrow vein; figure 5-19c illustrates the best position for the drift relative to the vein for the following advantages:

1. Hanging wall of vein is unbroken. Trouble can be avoided in stoping if hanging wall is not broken.
2. A chute to gather ore can be readily constructed in the drift with little or no widening.
3. The ore and waste can be blasted separately in two blasts for clean mining of the ore.

The vein structure, however, may be several feet wide, the ore lying on the footwall and waste vein material extending to the true hanging wall (Fig. 5-7). The soft vein matter will not stand by itself. The drift should be positioned as shown in

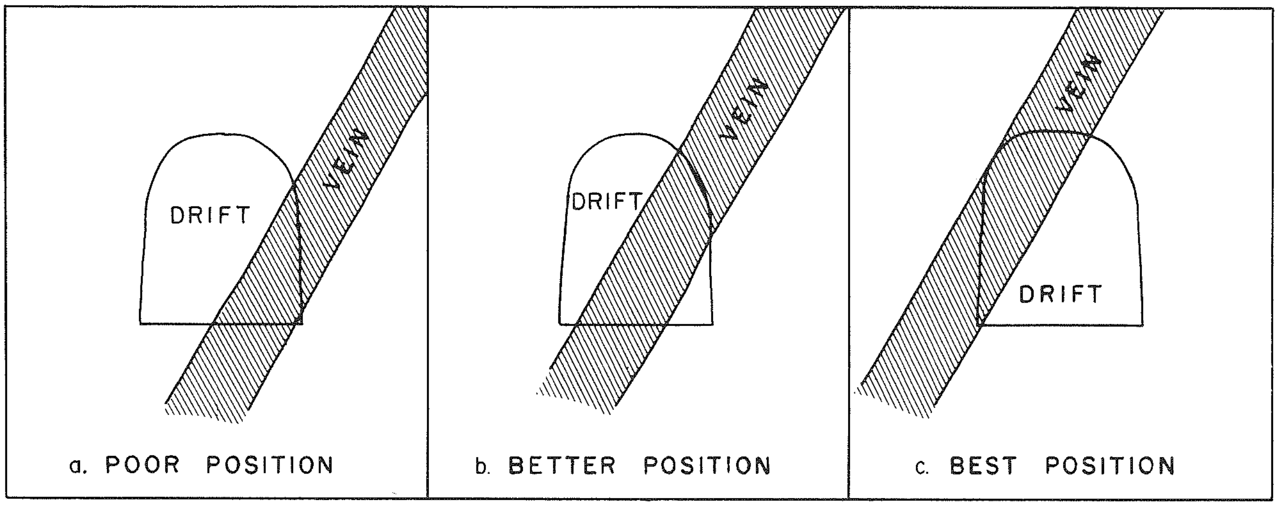


FIGURE 5-19.—Sketch showing position of drift in relation to vein.

Figure 5-19b, one side of the drift being on the true hanging wall. It is still a good plan not to break the hanging wall if it can be avoided.

The previous discussion applies mainly to small mines where the attitude of the ore body is unknown. The old rule of 'staying with the ore' is a good one to follow in new mines or narrow veins. Drifting in ore has disadvantages, however, in areas where the vein is wide, especially if much ore is to be produced from that level. The disadvantages are:

1. More support and maintenance is required for keeping the drift open, because most ore is weaker than the wall rock.
2. Cars being loaded from chutes may cause delays for other ore trains or service trains on the level.
3. Runaway chutes may tie up transportation until the spill is cleaned up.
4. Preparation of raise cutouts, other stope block preparations, or level maintenance may also cause transportation delays on the level.

To overcome these disadvantages, many mine operators have adopted the practice of driving laterals from which crosscuts are driven to the veins (Fig. 5-20). The rock from most of this development is waste, but the overall gain in mining efficiency by this practice usually offsets the added cost of driving in waste.

CHOICE OF RAISE LOCATION

As in level spacing, so in raise spacing—factors are frequently overlooked that may affect the costs of producing ore. Raises, like levels, cost money, hence the ore won from the stope influenced by this raise must be a maximum. Why are raises necessary? They are required to define the limits of the ore body, to connect levels, to provide ventilation, to mark off or establish the size of a stope, and to provide passageways for men, material, and ore. In most stoping operations in steeply dipping veins, raises are a necessity. True,

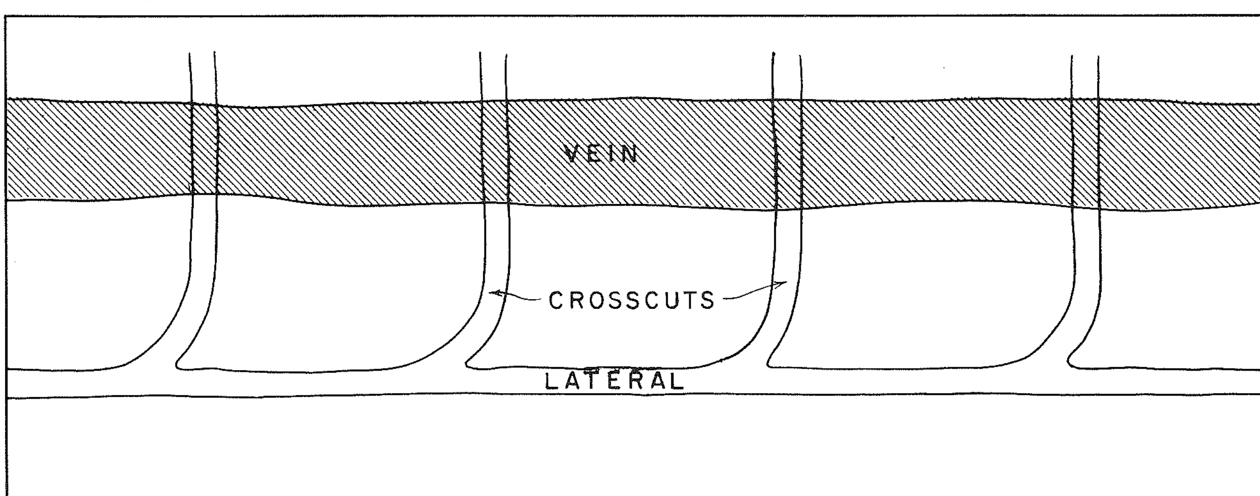


FIGURE 5-20.—Sketch showing lateral and crosscut development for wide veins.

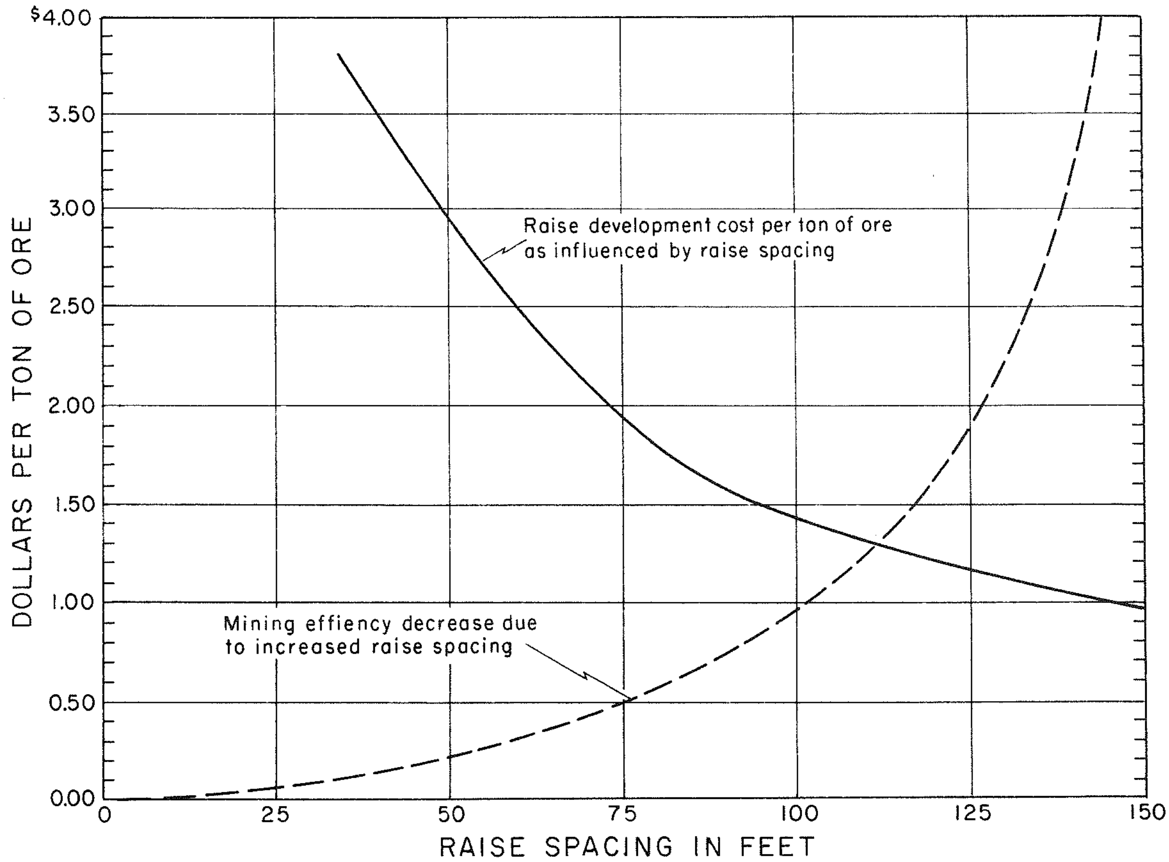


FIGURE 5-21.—Chart of factors which influence raise spacing.

raises are sometimes driven as an integral part of the stoping operation and therefore are not completed until the stope is nearly complete. In many places this may be sound policy, but problems encountered in this operation are numerous. The two most common are: (1) Pay to miners for the two kinds of work, if the mine is on an incentive system, and (2) ventilation. Scheduling the sequence of operations so that raising and stoping operations do not conflict is bothersome. Even if raises are driven as an integral part of the stoping operations, spacing of the raises is still a problem.

What factors influence raise spacing? Some of them are:

1. Local geological factors.
2. The mining method used.
3. The efficient recovery of ore from each raise.
4. If slushers and scrapers are used in loading operations, the length of scraping distance for maximum efficiency.
5. Time required to prepare a stope.

How do these factors influence raising spacing? Perhaps a hypothetical example will show. By using the same conditions as in the example for level spacing, and assuming a 250-foot level spacing, then for each 1 foot length of ore along the vein there would be $\frac{6 \times 1 \times 250}{10} = 150$ tons of ore. The cost per raise has been calculated as $22,000. The cost per ton of ore for different spacing of raises based on these calculations could be charted as shown in Figure 5-21 by making a few sample calculations as follows:

Cost per raise
Tons recovered through raise
equals
raise development cost per ton
of ore mined from stock

10-ft. spacing
$$\frac{\$22{,}000}{10 \times 150} = \$14.67$$

25-ft. spacing
$$\frac{\$22{,}000}{25 \times 150} = \$5.87$$

50-ft. spacing
$$\frac{\$22{,}000}{50 \times 150} = \$\ 2.93$$

100-ft. spacing
$$\frac{\$22{,}000}{100 \times 150} = \$1.47$$

150-ft. spacing
$$\frac{\$22{,}000}{150 \times 150} = \$\ .98$$

200-ft. spacing
$$\frac{\$22{,}000}{200 \times 150} = \$\ .73$$

This information produces the solid-line curve on Figure 5-21.

Omitting geological conditions or the physical conditions of the level, the factors that influence the distance between raise spacing would be:

1. The time element involved in any stoping sequence; that is, how fast can the ore be mined.
2. The efficiency and length of the scraper haul, or life of slides, etc., that may be used to remove the ore from the stope.
3. The added inefficiency of mining due to the increased length of the stope, which causes excess walking, repairs, and maintenance.

Unfortunately these items are difficult to evaluate in dollars and cents. Many mine operators do not keep enough records so that this information can be calculated, but most operators will agree that there is a definite optimum distance between raises for efficient mining.

We will assume for our problem in raise spacing that the aforementioned items can be reasonably calculated or estimated. How can this be done? First, if we estimate each item independently for the different trial distances between raises, we should arrive at a reasonable figure. We then add these independent items together for each trial raise spacing. By plotting this information, a reasonable curve should be obtained. In doing this for our particular example we arrive at the dashed-line curve on Figure 5-21. The two curves intersect at approximately the 110-foot spacing, which for these conditions shows that 110 feet between raises is optimum. All too frequently, past practice, as in level spacing, again dictates raise spacing. The spacing chosen in the earlier days may not have been scientifically chosen in the first place. Certainly, improvements in mining technique call for a revaluation of such expensive excavation every so often.

COORDINATION OF DEVELOPMENT ACTIVITIES

Coordination is important. Production lost in one working place because of some action in another place can greatly affect the total overall production cost. Work must be planned sufficiently ahead and carried out on schedule so job conflicts do not arise. A job conflict is shown by the following example:

A drift has been driven for considerable distance without raise cutouts being made. Correction of the depleted condition of the ore reserves requires raising and drifting at the same time. To start the raises, however, it is necessary to disconnect the air, water, power, and ventilation lines so that they will not be injured in the blast for the raise cutouts. Too, the muck must be cleaned up after the blast before the cars can go beyond the raise into the drift heading. Therefore, with each blast in the raise program, some time is lost in the drift. If several raises are to be started, even more time is lost in the drift. To avoid taking the service lines down, the raise miners may start the raise close to the drift heading. Two crews working so close together may have difficulty scheduling operations so that one does not interfere with the other. For example the raise miners may need to timber, but they have no room for timber storage; therefore, the timber must be brought in. The drift crew may be mucking; to hold them up while timber is brought in may cause lost production in the drift. Many other situations may arise where one crew interferes with the other.

Fortunately, good planning can do much to eliminate the aforementioned problems. For example, if the raise locations are known and the drift is far enough ahead, the drift miners can cut out for and drive the raise far enough that the raise crews do not interfere with the drift miners when they start in the raise or vice versa. Good drift miners can normally do both drifting and raise cutout operations more efficiently than can two separate crews while working in confined quarters.

Personnel trained in scientific management report that a job done right the first time almost always results in lower total unit cost. Therefore, planning the operation so that no time is lost in preparation or in crew interference results in lower costs for any job. Of course, it is true that information needed for planning such items as raise spacing is not always known, but if it can be determined, efforts spent in planning and coordination are well rewarded.

CAPITAL EQUIPMENT

CHOICE OF EQUIPMENT

One of the first tasks facing a mine operator is the acquisition of equipment for efficient mine operation. Not only must he determine what is needed for his mine, but he must select the proper size and amount. He should also decide whether he wants to rent or buy equipment, what type of power is most desirable, and what type of buildings or other installations will be required.

What is Needed?— Let us say that the problem is to develop a vein from the surface. Assuming that it will be necessary to have adequate equipment to drive the drift, the minimum necessary requirements in this modern day would be as follows: air compressor, rock drill, mine car, track and ties, pipe and fittings, air and water hoses, oilers, drill steel, bits, shovels, picks, bars, saws, axes, ventilation fan and fanbag or tubing, mucking machine, mechanic's tool box, pipe cutters, threaders, or groovers, and pipe vise; water tank, air receiver, building to house tools, workbench, and probably compressor, nails, bolts, track spikes, and timber or rock bolts.

These items are the minimum requirements for a drifting operation. In this day, it still may be possible to find men who will muck a drift by hand, hence the mucking machine may not be required. As a general rule, however, a drift can be driven more cheaply if adequate equipment, including a mucking machine, is available.

If it is decided to use diesel-powered load-haul-dump equipment, the mine cars, track, and mucking machine will not be required, but ventilation equipment will be necessary to dilute the diesel-exhaust fumes. Load-haul-dump equipment, because of its flexibility, versatility, speed, and high production rates, should be considered for initial operations, especially in adit-developed mines.

If a shaft is to be sunk, in addition to the above equipment requirements, except the mucking machine, the following extra equipment is necessary: hoist, hoist house, hoisting rope (steel cable), signal system equipment, headframe, cage for hauling men and car, pump and pipe, material for pump column.

After a mine gets into production, each drift heading or shaft-sinking operation would need most of the above equipment. It may be possible to shift certain pieces of equipment such as a drill or mucking machine from one place to another, but usually each crew must have complete equipment necessary for the job.

Each raise and stope crew will require: drill steel, bits, hoses, pipe, fittings, timber, axe, shovel, pick, saw, possibly a slusher and scraper, cable, etc.

As production in the small mine increases, not only will more mine cars be required, but means of pulling or pushing them must be obtained. Normally the size and number of cars and other haulage equipment depend upon the tonnage to be hauled in a day.

A deposit located close to the surface may be mined by open-pit or surface methods. The requirements for this operation on a small scale are: loading equipment (shovel, tractor, loader); hauling equipment (truck); combined loading and hauling equipment (scrapers); drills or some means of breaking rock; compressor; mechanic's kit: and hand tools.

As any mine develops, there is a need for ore bins and other surface structure necessary to facilitate the mining process, such as shops, change houses, storage areas, and offices.

What Size is Needed? — When determining what kind of equipment is necessary, the size or capacity must also be selected. For example, when selecting an air compressor, what size is needed for adequate air supply? For a drifting operation, the drill and mucking machine both require compressed air for operation. Fortunately the suppliers or manufacturers of this equipment will give the air requirements in cubic feet of free air per minute (cfm) at sea level. Most air-leg drills will consume approximately 100 cfm at 100 lb. sq. in. gauge pressure (psi) at sea level. A small-size mucking machine will consume approximately 250 to 300 cfm at 100 psi at sea level. Therefore, a compressor of at least 300 cfm capacity at 100 psi should be obtained. It is unlikely in a straight drifting operation that both the drill and mucking machine would be operating at the same time. If raising or stoping operations might be carried on concurrently, however, then of course a machine of at least 400 cfm capacity should be obtained.

Another factor in selecting compressors is that altitude affects the output of a compressor and also affects the requirements of a drill. The loss in capacity of a compressor for each 1,000 feet increase in elevation is about 3 percent. Thus, if the requirements of the drill and mucker are approximately 400 cfm and the machine is at an elevation of 6,000 feet, the compressor size must be increased to

$$400 + \left(400 \times 0.03 \times \frac{6{,}000}{1{,}000}\right) = 400 + (400 \times .18) = 472 \text{ cfm.}$$

It would be wise to obtain a 500+ cfm machine if the drill and mucker are to be operated together.

As the mine increases in size, so will the air requirements. If a mine has six working places operating, consisting of two drifts, two raises, and two stopes, it would be unusual if all the air machines were operating at the same time. Experience has shown that if there are six machines in operating places, only about 80 percent of the sum of the machine requirements will be required at any one time, because one of the machines will not be operating. In our example, if the six machines combined required a total of 1,250 cfm the compressor capacity would be 1,250 × 0.80% = 1,000 cfm at sea level. However, at an elevation of 6,000 feet, we must again consider the altitude factor, which in this case would require

$$\left(1{,}000 + 1{,}000 \times 0.30 \times \frac{6{,}000}{1{,}000}\right) = 1{,}180 \text{ cfm,}$$

so a 1,200-cfm machine would be required. The factor for the number of air machines used at any one time is as follows:

1- 3 machines	100%
3- 4 machines	87%
4- 5 machines	85%
6- 7 machines	80%
7-10 machines	75%
10-15 machines	70%

Although this example applies to air compressors, the same reasoning may apply to related equipment such as the number of haul units needed in a transportation system.

The stated capacity and the actual capacity obtained in practice are not always the same. For example, the capacity of a car may be rated as one ton of high-grade ore. Much ore is heavier than waste rock, therefore when estimating the tonnage of waste or lower-grade ore to be handled in a conveyance of definite volume, an allowance must be made for the difference in density. Often muck builds up on the car bottoms, further reducing car capacity.

In larger cars or trucks, the capacities are usually given for level loads. If the cars or trucks can be heaped, the actual tonnage or volume hauled may exceed the rated. Usually the suppliers of equipment have technical men on their staffs who will readily supply information on actual capacity versus rated capacity.

How Much is Required?—When purchasing equipment or supplies, all needs must be filled without oversupply. Oversupply is costly and also leads to waste of the items by the employees.

A factor in selecting mechanical equipment for mining is the availability of spares, i.e., what percent of the time will the equipment be in operation. For example, with six working places the purchase of an extra drill would be justified to keep a producing place in operation in case of breakdown of one drill. True, a drill costs considerable money, yet loss of production also costs money. Spare items may also be justified in larger equipment, especially if many units of any one item are being used. Examples would be trucks to service a power shovel or spare cars for an ore train.

For a small mine, the amount of time that a machine is out of operation for service (lubrication, adjustment, and minor repairs), should be considered when estimating output. Few, if any, pieces of mechanical equipment have 100 percent availability if worked continuously. Availability usually ranges from 60 to 95 percent. On some two - shift operations, a third shift may be used for servicing equipment. If only one shift is operated, a certain amount of time must be spent in service. Fortunately, most schedules are flexible enough to allow for service time.

Planning of needed supplies for an operation ensures an adequate supply, e.g., in a drilling operation the number of bits needed may be estimated either by actual comparison to a similar operation or from past records. Supplying too many causes waste because the extras are not appreciated; the employees feel that when a large supply is available, there is no need to be careful. Better record keeping and cost control may be an answer to the supply problem, but compelling supervisory personnel to do a large amount of paper work is undesirable and may defeat a good record-keeping or cost-control program.

COST OF OWNERSHIP

Owning real property and equipment costs money. Factors that affect the total cost of owning and operating mechanical and electrical equipment in mines are the purchase price, freight, installation costs, maintenance and repair costs, the possible salvage value, depreciation, investment costs, taxes, insurance, and fuel costs—if fuel is required. The purchaser wants to get his money back during the life of his purchase at a fair interest rate in addition to building a capital surplus so that new equipment can be purchased when the old is worn out.

The price of equipment commonly quoted is f.o.b. factory. To place the equipment in operation requires an additional expenditure for freight and installation, which may run to a large figure.

Cost of maintenance and repair of equipment is hard to estimate, especially when first used. Past operating records are useful if available. Sometimes other operators may give their cost data. A good maintenance program with well-trained servicemen may greatly reduce the cost of maintenance.

To arrive at some useful figure for future planning it is general practice in the mining and construction industry to figure that the cost of maintenance and repairs on equipment that has hard usage, such as rock drills and mucking machines, is equal to the original cost. Labor costs just about equal the cost of supplies and parts in repairs and maintenance.

Fuel or power costs are major items in the cost of operation of most equipment.

When a machine is placed in operation it begins to deteriorate; in fact, even if not used it may become obsolete, superseded by improved models. Worn or obsolete equipment must be replaced. The U.S. Treasury Department recognizes this fact and allows a reasonable deduction from gross income for wear and obsolescence (depreciation allowance). For most small mining enterprises the depreciation schedules filed with the federal income tax return can be those used in the operator's accounting system (see also discussion under Income Tax in Chapter 7). Depreciation calculations involve the useful life of the machine and its salvage value. The Internal Revenue Service issues a publication (Publication 534) that gives the average useful life of equipment used in mining operations. This schedule pertaining to mines is reproduced as Table 5-3. The number of hours a day that equipment is used affects its useful life, which may therefore be much more or much less than that in Table 5-3.

The three systems generally used in calculating depreciation are: the straight line, declining balance, and sum of year's digits methods. Figure 5-22 shows a chart of the three methods as they may be applied to a particular item. In some cases, it is to the advantage of the investor to recover his investment in equipment as rapidly as possible. (The U.S. Treasury Department will allow only certain approved methods of calculating depreciation for more rapid return of investment.) As illustrated in Figure 5-22, two of these methods are the declining balance and the sum of year's digits. With the sum of year's digits system there must be a salvage

TABLE 5-3.—Average useful life, in years, of equipment and machinery used in mines and quarries (from Publication 534, Internal Revenue Service, 1974).

Asset Guideline Classes and Periods, Asset Depreciation Ranges, and Annual Asset Guideline Repair Allowance Percentages.

Asset guide-line class	Description of assets included	Asset depreciation range (in years) Lower limit	Asset guide-line period	Upper limit	Annual asset guide-line repair allow-ance, percent-age
00.00	DEPRECIABLE ASSETS USED IN ALL BUSINESS ACTIVITIES, EXCEPT AS NOTED:				
00.24	General purpose trucks, including concrete ready-mix trucks and ore trucks for use over the road:				
00.241	Light (actual unloaded weight less than 13,000 pounds)	3	4	5	16.5
00.242	Heavy (actual unloaded weight 13,000 pounds or more)	5	6	7	10.0
10.0	Mining: Includes assets used in the mining and quarrying of metallic mines (including sand, gravel, stone, and clay) and the milling, beneficiation, and other primary preparation of such materials)	8	10	12	6.5

value. These two methods are used mostly for calculating depreciation on equipment that depreciates rapidly when it is first new, e.g., trucks and compressors.

The simplest and most commonly used method of calculating depreciation is the straight line method, in which the amount allowed each year is found by the following formula:

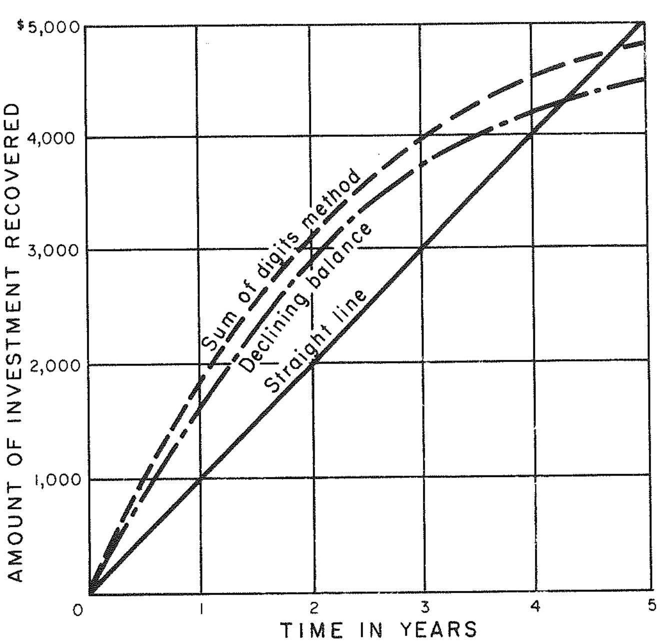


FIGURE 5-22.—Approximate curves for different methods of computing depreciation on a single piece of equipment costing $5,000 and having a useful life of 5 years. A salvage value of $500 is used in the sum of year's digits method only.

$$\frac{\text{Purchase price} - \text{Salvage value}}{\text{Useful life in years}} = \text{Amount allowed for depreciation per year}$$

In the following examples only the straight line method will be used. A qualified accountant should be consulted to determine whether systems other than straight line can be used to advantage for computing depreciation. Again to remind you, to change from an established system of calculating depreciation to another involves complications.

Interest on money invested, taxes on the equipment, and insurance are all costs to the owner. These items vary from place to place, but are usually estimated as a percentage of the 'average investment', which is the sum of the yearly values of the equipment during the time it is depreciated divided by the number of years of depreciation, calculated as follows:

Original cost of equipment $100.00
Estimated useful life .... 10 years
Annual depreciation .... $100 ÷ 10 = $10.00

Beginning of year	Cumulative Depreciation	Value of Equipment
1	0.00	$100.00
2	10.00	90.00
3	20.00	80.00
4	30.00	70.00
5	40.00	60.00
6	50.00	50.00
7	60.00	40.00
8	70.00	30.00
9	80.00	20.00
10	90.00	10.00
11	100.00	0.00
	TOTAL	$550.00

Average investment = $550 ÷ 10 = $55

Average investment as percent of original cost = $\frac{55}{100}$ x 100 = 55%

Yearly taxes, insurance, and interest average 15 percent of the 'average investment'. Of this 15 percent, approximately 3/5 is interest and 2/5 taxes and insurance. The general formula for calculating average investment is:

Average investment = $\frac{n + 1}{2\ n}$ x 100 = precent of total investment where n = number of years in depreciation period.

An example of this cost of ownership per year on a piece of mining equipment costing $5,000 follows. Table 5-3 gives the normal life as 10 years, and it is assumed that there is no salvage value. Therefore, calculating with straight line depreciation:

Depreciation = ($5,000 — 0) ÷ 10 = $500 per year

Taxes and insurance = 15 percent of average investment

15% $\frac{(n + 1)}{(2\ n)}$ x $5,000 = 0.15 (11/20) x $5,000 = $412.50 per year

Maintenance and repair = 100% total cost ÷ useful life $5,000 ÷ 10 = $500

Yearly cost of ownership $500 + $412.5 + $500 = $1,412.5

Total cost of ownership = $14,125

Using the same information, and recalculating on the basis of a useful life of 5 years*, the total yearly cost comes to $2,450 or a total cost of ownership of $12,250.

Often it is more desirable to use the percentage basis rather than actual dollars. The following example shows how this is done:

Total cost = 100%

Depreciation = $\frac{100\%}{10}$ = 10%

Average Investment = $\frac{10 + 1}{20}$ = $\frac{11 \text{ x } 100\%}{20}$ = 55%

Taxes, interest, and insurance 15% x 55% = 8.25%

Maintenance = $\frac{100\%}{10}$ = 10%

Total yearly cost of original investment 28.25%

* These simple examples show how the yearly costs of ownership may be calculated. When all of the costs, taxes, insurance rates, and useful lives are known, the calculation can be much more accurate and complete.

INITIAL INVESTMENT

When starting or rehabilitating a mine, a large outlay of money for labor and supplies is needed before there is any hope of return. The initial investment should be kept as low as possible, yet large enough to meet these costs adequately.

A great deal of equipment is needed to run a mine. Capital items such as compressors, hoists, drills, and pumps may be available by leasing on a weekly, monthly, or longer term basis. If the venture is a failure, the operator merely returns the equipment to the owner and the rent is charged off as a loss.

Some equipment can be classified as expendable, but most expendable items are those that are consumed in normal mining, such as explosives, timber, and drill bits. Items that either tend to wear out rapidly or to get lost or misplaced are also placed in this category. If used in areas where corrosion is extreme, track and pipe may be listed as expendable items. As a general rule, all expendable items must be purchased outright, because they will be consumed in the mining operation.

Leasing Equipment.—There are two general types of equipment leases, the straight lease and the lease or rent-purchase option. In the former, a certain number of months rent usually must be paid in advance before the owner will release the equipment. Too, there is a provision in most leases that the lessee must pay all repair expenses and the equipment must be returned in as good condition as it was when taken out, normal wear and depreciation excepted.

The second procedure is really not a lease but a form of purchase contract. In this plan, a payment is made, usually several periods of rent in advance, and the machine is taken out as in the ordinary lease. After a certain time limit stipulated in the contract, the lessee may decide to purchase the equipment. Commonly the previous rent payments, or a stipulated part of the payments, may apply toward the purchase price.

There is a drawback to equipment leasing. As a general rule, only used equipment is available. Therefore, the maintenance cost on leased equipment tends to be greater than on newly purchased equipment. Even with added maintenance cost, however, the reduced capital requirements for this equipment may be an advantage to a company having small financial resources.

Rates for equipment leasing vary widely. If a piece of equipment is new or nearly new, the rental price is dependent on the useful life of the machine. Of course, the basic question comes down to "how much does it cost?". This depends on how costs are considered, and the situation of the mine operator. As far as direct costs are concerned, leasing will always cost more than outright purchase in the long run. But profits on working capital released by leasing may more than offset the added direct cost of leasing. Too, this available capital may mean the difference between whether the operation starts or not.

The decision whether to lease or purchase normally is determined by the amount of capital available and the estimated ore reserves. If the ore reserves are uncertain, and capital is small, leasing is undoubtedly best, for the following reasons:

1. Not as much capital is required.
2. Savings in property taxes may be appreciable
3. If the mine fails, equipment disposal is no problem.
4. If the mine is a success, no money is involved in purchase of equipment for exploratory work that may not be adequate for mining operations.

If ore reserves are definitely established, the direct purchase plan becomes more attractive because it does offer the lowest overall cost. The equipment requirements are difficult to foretell during the prospect stage, however.

Portability of Equipment.—An important cost of any enterprise is the set-up time or time necessary to prepare the place for working. Many operators completely overlook this cost or greatly underestimate it. Moving heavy equipment from one place to another requires skilled movers in order to avoid danger to the employees or harm to the equipment. In a small operation, skilled equipment movers are seldom available.

Industrial consultants have shown by repeated studies that the larger sizes of specialized equipment normally do their assigned task at a lower cost per unit than do the smaller sizes. The installation cost of factory equipment is a very small part of the total cost, however, because once the machine is installed, it is unlikely to be moved until it wears out. In a small mine or prospect, the situation is different. Most of the equipment, especially that used underground, must occasionally be moved to a new location. Equipment light in weight or mounted on wheels or skids can be readily moved. Therefore, in determining what equipment to buy, the job must be studied. If the machine does not have a heavy production schedule and it must be moved from one location to another frequently, a lighter, portable machine should be purchased. The increased work output of a machine of larger capacity will be lost because of the longer time involved in relocating the equipment.

Of importance in selection of equipment for underground use is the overall size. Space is at a premium in underground openings, so sizes should be checked. Many operators have been embarrassed to find after they purchased equipment that it would not fit into the location selected for it.

Contracting.—Contracting certain portions of mine work to an independent contractor is common practice by mine operators. This discussion will not concern itself with the so-called mine-operating contract or piece-work system. An independent contractor is one who supplies most if not all of his own equipment, provides all of his own labor, and pays for all expenses of the operation.

After a property has been examined for ore reserves or possible ore reserves, or if some new development is necessary, the next step may be drilling, drift-driving, crosscutting, or shaft-sinking operations. These operations may be called 'one-shot' operations, that is, if ore is found as a result of this one development program, operations at the mine will continue. If no ore is found, operations will cease.

To save the cost, time, and trouble of acquiring all the necessary equipment, one can hire independent contractors who will drive certain types of development headings at a price of so much per foot for certain specified lengths or a flat price for an entire job. The contractor will provide all equipment, supplies, and know-how to do the job. This know-how is very important because in setting up or starting any job considerable time is lost in learning what to do. Most of these contractors have this experience and can do a creditable job. Therefore, contracting the job eliminates not only the ownership problems but also the time required to learn how to do the job. An independent contractor will complete many jobs at a lower price than the mine operator can, especially if the operator must purchase the equipment. Many large mining companies contract certain types of mining jobs to specialists. The companies, even though they have the experience and know-how, have found that independent contractors who are specialists in their field can do the job cheaper than they can, for many reasons, among which are:

1. The mining company has a full-time job producing ore at its scheduled capacity.
2. Obtaining and training the crews involves both time and expense.
3. Local conditions such as union contracts and work rules may hinder a specialized job.

One must be careful in choosing the contractor, because the owner or operator of a mine may be responsible for some of the acts of the contractor. Examples of this may be liability for Industrial Accident Insurance if the independent contractor's workmen are not covered by workers compensation provisions. The mining property may become subject to material and mechanic's liens through certain actions of the contractor under certain conditions. This will be discussed further under 'Insurance' (Chapter 7). Not only should the contractor be reputable, but the contract agreement should be carefully worded to avoid any later complications.

In summary, for short jobs, the independent contractor may do the job cheaper, because he has the equipment, know-how, and men for the job. For long-term jobs, overall cost may be less if the mine operator buys or leases the necessary equipment, organizes a work force, and does the work himself.

POWER REQUIREMENTS

One of the problems that a mine operator must face when he buys mechanical equipment is what type of prime mover he should purchase—gasoline engine, diesel engine, electric motor, or air motor?

The power requirements of a mine depend on its size and its ore reserves. For most single-heading development work, except for large contract jobs, gasoline power will ordinarily be preferred because of its initial low price and because it is used only part of the time. As the mine grows and more headings are needed, a diesel-powered compressor may be required. If the mine grows to be a major producer, electric power will be a necessity, because of the wide diversity of power requirements.

For large operations, electric power is almost a necessity because of its efficiency and convenience. Electric motors can be purchased in all sizes, shapes, and voltage requirements, and they can be operated under almost any conditions wherever electric power is available. Gasoline and diesel engines, on the other hand, require an ample supply of air for efficient operation, and ample ventilation must be provided to carry away the dangerous exhaust fumes. Most gasoline and diesel engines can be mounted in only one plane, i.e., near horizontal, for efficient operation, whereas electric motors, at least small horsepower types and special larger types, can be mounted in almost any plane. Gasoline and diesel engines normally require much more service and maintenance than do electric motors.

Air-powered equipment is used underground because it is flexible and light in weight. An air motor cannot be injured by overloading. A supply of compressed air must be available, however, and to compress this air one of the other types of power must be used.

Gasoline Engine. — The main advantage of gasoline engines over other prime movers is that many types and styles are available, to about 50 brake-horsepower. A good choice can be made for any one job. All mechanics or mechanically inclined persons are familiar with the operation of gasoline engines, hence they can be more readily repaired than diesel engines. Gasoline engines cost only one-half to three-fourths as much as diesel engines of the same power rating. If trucks, hoists, and all other equipment at the mine are gasoline driven, then only one type of fuel is necessary. This may help the supply situation. Too, a gasoline engine delivers good power ratings over a wide range of revolutions per minute, which may be desirable in some types of equipment, automobiles for example.

The disadvantages of gasoline-powered equipment are that cost is high, efficiency is low, and the engine can be used only above ground. Because gasoline engine exhausts produce as much as 20 percent carbon monoxide, a very deadly gas, gasoline engines should never be used in underground operations. In larger horsepower sizes, gasoline engines are not readily available, because the diesel is much more efficient.

Diesel Power. — Diesel engines are made in high horsepower ratings, which make them ideal for equipment requiring much power. One advantage of diesel engines over gasoline engines is that in the larger sizes the diesel engine is more efficient and burns a cheaper fuel. For engines that consume considerable fuel, the saving in fuel may more than offset the higher initial cost in a short while. A diesel engine is more dependable and normally requires less maintenance than a gasoline engine. The diesel ignition system is far less complicated than that of gasoline engines. Only diesel engines are used as standard equipment in larger-capacity portable compressors.

Diesel engines are heavier and cost more than gasoline engines in comparable sizes. Too, a diesel engine is efficient only over a narrow speed range; most manufacturers recommend that the engine operate within a certain range under load. Another feature of diesel engines is that they are often difficult to start in cold weather unless special starting fuels are used. For repairs or maintenance, except simple greasing and oil changes, a mechanic trained in diesel repair is needed.

Diesel-powered equipment is now extensively used in underground operations. With proper control, regulation, and maintenance, such machines can be safely used in most underground situations. Of course, flammable diesel fuel must be handled carefully underground, but with proper care, this danger can be minimized. The principal danger from diesel engines used underground is the toxic exhaust gases and the possible release of sparks, which could ignite flammable material. The toxicity of exhaust gases can be controlled by proper fuel selection and proper maintenance and operation of the engine. Although the theoretically correct air-fuel ratio by weight in a diesel engine is 15:1, minimum formation of carbon monoxide and other toxic gases is ensured under an air-fuel ratio of as much as 20:1. This ratio does not greatly impair the efficiency of the engine. The engines should not be allowed to idle in underground headings for long periods of time, and low-sulfur fuel should be used to ensure against sulfur dioxide in the exhaust.

The engine must be equipped with a spark arrester and an appropriate exhaust conditioning device or scrubber, which may use water or some other chemical to purify the exhaust. Because of the common use of diesel engines underground, most manufacturers can supply their equipment with all of the necessary modification for this use.

It must be emphasized, however, that it is virtually impossible to provide sufficient ventilation air to a heading where a diesel engine is working unless forced or mechanical ventilation is used. Therefore, when diesel equipment is being considered for underground use, ventilation methods and equipment must be selected at the same time.

Electric Power.—The efficiency and convenience of electric power have been mentioned. The big advantage is that near populated areas it is cheap. Electric motors cost less than gasoline and diesel engines of the same power ratings. They are available in all sizes and shapes and will operate in all kinds of atmosphere.

The disadvantages of electric power are: first, electricity is not readily available at every property; and second, it is dangerous unless great care is taken in its distribution. Because many mines are in isolated areas, power must be brought to the mine. This means that right of way must be obtained and the power line built. Normally, the mine operator must either install or pay for the installation of the power line and transformers. The power company may buy the line, however, by means of rebates over a period of time in the form of reduced power bills to the mine operator.

BUILDINGS

Because of the severe weather in many mining areas, buildings are almost a necessity both for housing equipment and for the comfort of employees. If the mine or prospect is active only during the summer months, the primary requirements of the buildings are: (1) to keep weather from damaging the equipment; and (2) to serve as storage for tools and supplies. Almost any type of shelter will serve for this purpose. Keeping thieves from stealing equipment is a problem at isolated mines. Buildings are frequently prowled because the thief can work at his leisure. The author has found that most thieves and prowlers will not enter underground workings. Therefore, the safest place to store lightweight and portable equipment is underground. If the mine is to operate during the entire year, the buildings should not only be insulated for protection from the cold but also be provided with means for heating them. For year-around operation, the structures must be both durable and sturdy, which in turn makes them more costly to construct.

Considerable funds can be expended on construction, so the operator should determine for what he is building. In prospects and 'one-shot' single-heading developments, the structures should be kept at a minimum and made portable if possible. If the development program is successful, needed buildings can be constructed later.

Portable fireproof steel buildings should be investigated, because their cost is not much greater than that of completed wooden structures, and they can be more readily moved to a new location if desired. Fire is a hazard, and some mining codes state that buildings constructed of flammable material cannot be located closer than 50 feet to any main shaft or tunnel portal. For winterizing a mine, it is usually convenient to have everything near the portal, but to comply with state laws, structures located near the portal must be made from material that is nonburnable.

As the mine progresses and new buildings become necessary, thought should be given to the arrangement or location of the buildings for efficient operation. Buildings, unless constructed of nonburnable material, should be spaced far enough apart so that, if one should burn, the others will not do likewise. They should not be so far apart that too much time is lost going from one to the other. The topography or 'lay of the land' may be the governing factor, but the fire hazards and travel time should be considered in locating the buildings for the most efficient layout.

What is the minimum requirement for a mine with 20 employees operating on a year-around basis and developed by a shaft? A hoist house and a compressor house are necessities. These two pieces of equipment can be located in the same building, unless the compressor noise affects the hoist operator so that he may not hear the signal bells properly. Around a continuous noise, some people become very nervous and jumpy. The hoist and compressor can be placed in different buildings, or at least a noise-reducing partition built between them. A combined equipment-repair and carpenter show would be convenient, and a change house and office would be required.

Thus, two or three buildings would be required —a combined change house and office, a combined hoist house and workshop, and if it is desired to keep the hoist and compressor separate, a separate compressor house. One advantage of having the hoist and compressor in the same building is that the heat from the compressor greatly aids in warming the building in the cold season.

Other points to consider when designing buildings are: large doors should be provided so that the hoist and compressor can be removed or replaced with a minimum of building alteration, and fire extinguishers should be readily available in all buildings. Equipment should be so spaced that it can be taken apart for repairs without tearing out a wall or roof.

TRACKLESS EQUIPMENT

Since the publication of the first edition of this handbook, manufacturers of mining and earth-moving equipment have developed rubber-tired equipment that is very efficient and that can be used to considerable advantage in many mining situations. This equipment is powered by air and diesel engines or electric motors. Perhaps the most versatile equipment is the diesel-powered load-haul-dump unit. It is very flexible and does not have to depend on an outside source of power. It carries its own engine. Too, it can work underground or on the surface, and it can do several different jobs. The smallest units have a capacity of ½ yard, the largest more than 10 yards.

Load-haul-dump machines have done away with track, cars, separate mucking machines, and ore bins on the surface. The machine can load

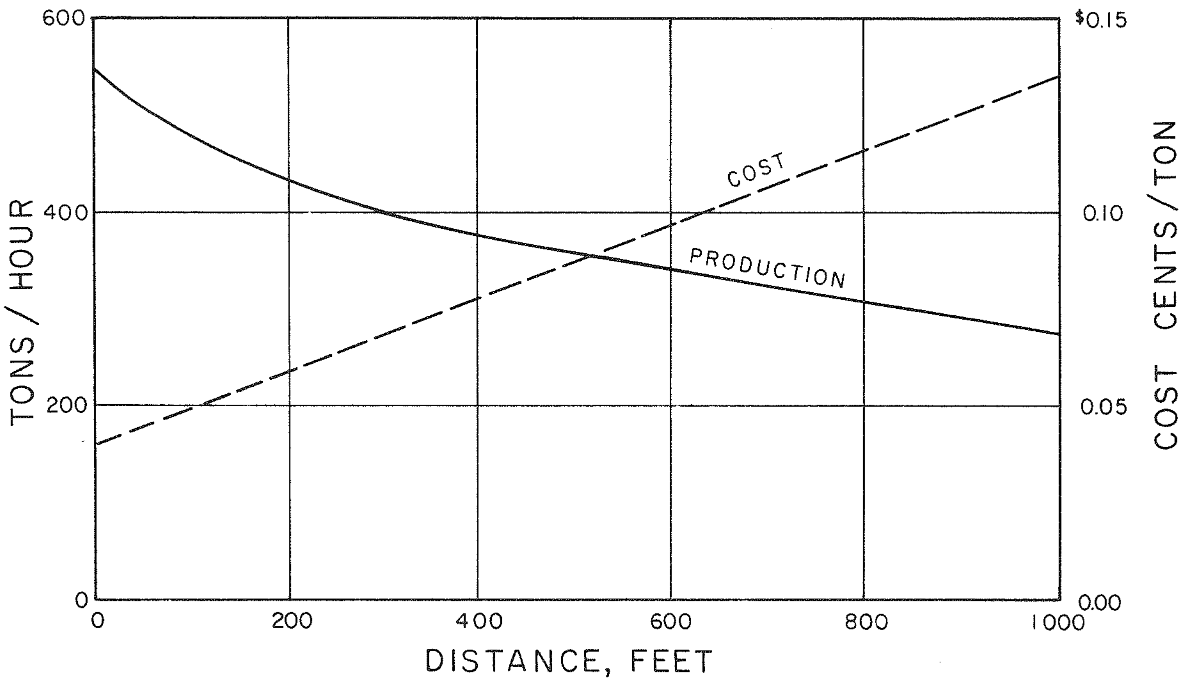


FIGURE 5-23.—Graph of load-haul-dump production figures and costs depending on distance.

ore trucks and can transfer waste and other surface material as needed and can tram or haul as far as 1,000 feet with fair efficiency so should be considered for initial prospecting and development. See Figure 5-23 for a cost/ton graph of a typical load-haul-dump machine of 6-yard capacity. Most manufacturers of this equipment will be happy to supply graphs similar to Figure 5-23 for their equipment. Drill jumbos too are now mounted on specially designed rubber-tired units, and many are mounted on the back of diesel-powered trucks or tractors. These mobile units do away with much of the delay caused by setting up and installing track-type equipment. Many jobs can be completed with this mobile equipment before the operator could get ready with track-type equipment. These machines are well suited to driving horizontal development headings, but they are also satisfactory on inclines or grades as steep as 15 percent. If much production is to come from these inclines, however, it is best to keep the grade at or below 10 percent because most machines lose efficiency on grades exceeding 10 percent.

The author had the privilege of visiting some of the underground iron mines in Sweden, and in one of the mines near Kiruna, special diesel-powered trucks of 40-ton capacity were carrying ore up a 10 percent incline for a total vertical distance of 350 feet at a cost comparable to sinking, equipping, and hoisting in a vertical shaft.

The principles discussed previously in this chapter still apply, whether track or rubber-tired equipment is used. Rubber-tired equipment is expensive, but when all costs are considered in developing and opening a deposit, using such equipment initially may be the best way to develop a deposit. It must be emphasized, however, that using diesel-powered equipment underground requires adequate ventilation. Therefore, a ventilation system must be installed at the start of any underground development work.

LEGAL AGREEMENTS

Of paramount importance to any mining enterprise are clearness of title to the property and good workable leases or contracts. The laws that affect contracts, real and personal property, agency and other business relations apply to all mining enterprises. A poorly or improperly worded lease, contract, or deed may cost the mine operator much money if a misunderstanding arises. The services of a good attorney are required to pass judgment on legal questions that arise in negotiations for mining properties and during the operation of the mine. Many mine operators and owners seldom call on the services of an attorney until after they get into legal troubles. Therefore, a short discussion of property transfer, fixtures, and lease agreements will be considered in this work.

Property interest, sometimes called possessory title, in an unpatented mining claim is regarded as real property between the locator of the claim and everyone else except the U.S. Government. A fee-simple title is normally regarded as the best title or ownership available to real property, but not until a claim is patented does the claim owner, or patentee, have what is normally regarded as a fee-simple title, because then and only then is his interest in the claim paramount over everyone else, including the U.S. Government. Before patent issues, the U.S. Government is the paramount proprietor because it must pass upon the locator's claim to the ground and it is the agency that issues the patent.

In Montana, for example, possessory title to a valid unpatented mining claim is treated the same as other real property, which can be bought, sold, conveyed, and leased, and it will pass by descent. Capital stock in mining corporations that own mining claims is not real property but personal property. The disposition of real and personal property may be different under certain circumstances. Because mining claims are regarded as real estate, all matters pertaining to the transfer of title or ownership or possessory rights must be in writing except for a lease that is definitely less than one-year duration.

One common method of transfer of possessory rights is by leasing. In a lease, the owner or title holder (lessor) gives to another party (lessee) the right to work his claim and produce ore therefrom while he, the lessor, retains a percent (often called royalty) of the total mineral wealth produced for his interest or rent. Three types of leases are common in mining; these are (1) straight or regular lease, (2) the lease and option or lease and bond, and (3) the sublease or 'split-check' lease.

The straight or regular lease gives the lessee, not the owner or lessor, the right of possession of the mine including the right of ownership of the mineral when taken from the ground, subject to the landowner's interest. A mining lease therefore is similar to a regular real estate lease in terms of time, and the rent payment for the property is the lessor's royalty from the total ore produced. Provisions may be included in the lease that make it more complicated or may change its character so much that instead of a lease it may be a license, a contract on shares, or an option for a lease. The law treats these types of agreements differently in certain aspects. Therefore, an attorney should be consulted for his opinion on how the rights of the parties may be affected by these complicated agreements.

A lease and option (or lease and bond) is an ordinary mining lease with the added provision that the lessee may purchase the mining property on the terms stipulated in the lease agreement, which is called the option. The purchase agreement is fulfilled in numerous ways such as by cash purchase, by a time purchase, or by provisions where the previously paid royalty in the lease counts toward the purchase price. These agreements become complicated because the taxes applicable in each of the above situations differ.

The third type, the split-check lease, is one in which the mine is divided into several small leasing areas or blocks and each of these blocks is leased to a miner or to a group of miners (termed sublessees). Or the whole mine, for a short term, may be leased or subleased to one or a group of sublessees. Commonly the sublessees provide the labor and some of the supplies, and the lessor or company (which may be the owner or a lessee under one of the other types of lease) provides the other necessary supplies and the equipment for mining. The proceeds from this endeavor are split between the sublessor and sublessee according to the terms of the sublease, hence the term 'split-check' lease. The liabilities of individual parties to this type of lease (lessor, lessee, and third parties) may be difficult to determine.

Many operators and prospectors feel that these long legal instruments are complicated, expensive, and unnecessary. What they want is a simple gentleman's agreement. If large quantities of good ore are found, however, many differences over these simple agreements are sure to arise, and court action may be necessary to straighten them out. Well-drawn legal instruments will save litigation. An instrument affecting the title to or the possession of real property should be recorded in the county courthouse to protect all parties concerned.

The law of fixtures applies to mines, and one should consider these in the lease. Fixtures are goods that are normally regarded as personal property until they are firmly affixed to real property, at which time they become part of the realty. When certain items become fixed to the property, they cannot legally be removed unless provisions for doing so are stipulated in the agreement. An extreme example of fixtures is paint. When paint is purchased in a can, it is regarded as personal property, but when it is applied to a building it becomes part of the building or a fixture. By law, certain items are deemed fixtures when installed on mining claims by a lessee or sublessee. These items may include sluice boxes, flumes, hoses, tracks, cars, pipes, blacksmith shops, mills, or other heavy equipment that is rigidly affixed to a solid base. If nothing is said in the lease, by law these items stay with the property at the termination of the lease. But these items may remain personal property if, by an express agreement between the parties, they are to remain such. This right, however, holds only between the parties who have notice of the contract.

Properly prepared, signed, and recorded legal instruments may save needless and costly litigation. The time to make these agreements is when negotiations are being made for the property and not at some later date.

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CHAPTER 6 — PRODUCTION COSTS

By
K. S. STOUT and D. J. EMBLEN

INTRODUCTION

The ultimate goal of any mining operation is to receive a gross income sufficient to cover all costs plus an amount left over to enable the owners to realize a profit. Profit, then, is the residual amount remaining after costs have been met. What is the nature of these costs that have first claim against gross income? It is the purpose of this chapter to examine these costs and to suggest ways to estimate and control them. Basically costs are of two types: (1) development and starting costs, and (2) operating costs.

Development and starting costs represent all expenditures made to discover the nature and extent of the ore body, to make sure that the ore blocked out can be extracted profitably, and to erect the necessary surface buildings and install the basic machinery. When operations are directed principally to the extraction of the ore blocked out, the starting stage has ended and the operating stage has begun. Costs incurred from that point on are regarded as operating costs.

The question most frequently asked an engineer or mining consultant is, "How much will it cost?" This question may refer to sinking a shaft, driving a drift, or mining ore. Of course, the answer will depend upon what is to be done, and this in turn will depend upon numerous variable factors such as:

1. Is the ground self-supporting or must it be supported by timbering?
2. Is the mine located near a city or town and does it have easy access to roads and railroads?
3. What type of equipment is available? Is it reliable?
4. Is equipment to be rented, purchased, or borrowed?
5. Are skilled workers and supervisors available?
6. What surface work must be done to get started?

These and many other variables must be considered before a definite answer can be given to the question, "How much will it cost?" We will try to provide guideposts that will enable one to estimate how much it is going to cost to start and operate a mine.

STARTING COSTS

Before mining operations can begin, certain expenditures must be made for buildings, building sites, and equipment. Each mine will require different expenditures because no two situations are exactly alike. To illustrate some of the preliminary work that must be done before a mine can begin to produce, we will assume that a small mine is to be started. The ore body has been blocked out, and a site for the necessary buildings has been selected. Before any building construction can take place the site must be leveled. For this operation a bulldozer operator is hired at an hourly rate of $40. Bulldozer rates range from $20 to $50 an hour depending upon the nature of the job to be done and the size of the equipment required to perform the task. An operator will usually charge travel time for his equipment. We have assumed that the total cost of leveling an area sufficient for all the necessary surface equipment amounts to $1500.

Next on the list is the cost of buildings. It is estimated that rough buildings will cost approximately $12.00 a square foot. Two buildings are required, a hoist house and a compressor house. If the hoist house is 15 x 30 ft., it will cost approximately $5,400. A compressor house 12 x 12 ft. would cost $1,728. Ore bins of 20-ton capacity will probably require $2,500 to construct, and an additional $2,500 will be needed for the headframe.

In addition to these construction costs, a certain amount of mining supplies and equipment must be acquired. These items will include cars, track, or trackless equipment, pipe, pipe fittings, timber, rope, sheave, cages, ventilation fan, and hoses. Many of the items can be purchased secondhand; nevertheless, the total cost is likely to be close to $10,000. Of course, a truck will be needed, and a used but serviceable one can be purchased for $3,000 to $5,000. To be on the conservative side, $2,000 should be allowed for miscellaneous items such as surveying, assaying, and legal work.

The following summarizes costs so far:

Headframe	$ 2,500
Buildings:	
Hoist house (15 x 30 ft. x $12.00)	$ 5,400
Compressor house (12 x 12 ft. x $12.00)	$ 1,728
Ore bin (20-ton)	$ 2,500
Surface leveling	$ 1,500
Total surface work	$13,628
Supplies and equipment	$10,000
Truck	$ 3,000
Miscellaneous	$ 2,000
Total initial investment	$28,628
Rounded off	$30,000

Additional equipment such as a hoist, compressor, and drills must be acquired before operations can begin. Equipment of this type can be rented, thereby saving a considerable amount that would otherwise be required in an initial investment. The amount of rental charge will, of course, depend upon the availability, size, and type of equipment desired. The monthly rental charge is about 1/30 to 1/8 of retail price.

Let us assume that the current retail price of a hoist is $6,000; of a compressor, $12,000; and of a drill, $1,500 — a total of $19,500. A realistic estimate of the monthly rental charge for these three items of equipment would be 1/15 of the total or $1,300. Obviously, it will take time for production to reach the point when the company will be receiving an income; therefore enough money should be available to pay at least six months rent. This would amount to $7,800 or $8,000.

A conservative estimate of the amount of investment required to get a small mine into operation would be approximately $38,000 ($30,000 + $8,000). Money spent getting a mine ready to produce, including labor cost, represents a cost that must be recovered before a profit can be earned. This cost is not charged against income in total as soon as production starts, however; the usual procedure is to write off the equipment as depreciation. The intangible portion of the initial cost is also written off over a period of years (capitalized). The accepted method is to relate the initial investment to the estimated ore reserves, thereby assigning a portion of the cost to each ton of recoverable ore. The following formula is used for this purpose:

$$\frac{\text{Intangible starting costs}}{\text{Estimated tons of ore}} = \text{Starting cost per ton of ore}$$

This cost factor multiplied by the number of tons of ore produced during a given period gives the amount of starting cost to be written off and charged against income for the period. Thus: Starting cost per ton $\times$ tons produced equals starting cost charged to current operations.

OPERATING COSTS

It is not always easy to determine when the development stage ends and the operating stage begins. Even during the development period, some commercial ore will be produced and sold. When most of the preliminary work has been completed, and emphasis is on getting out ore for sale, the operating stage has begun.

Costs incurred to carry on operations are operating costs and must be charged against the revenue obtained from the sale of ore. It is helpful to management when analyzing mine costs to have operating costs classified into (1) direct costs, and (2) indirect or redistributable costs. It is also useful in accounting for costs to have this two-fold classification.

Direct costs would include the cost of labor involved in the direct extraction of ore, such as miners, quarrymen, and surface men. Also supplies used in mining operations would be treated as a direct cost. Examples of such supplies would be explosives, drills, pipe and pipe fittings, track equipment, repair parts, and hose connections for water and compressed air.

Other expenses, as important as direct labor and supplies, apply to several locations rather than to a specific operation such as excavating a drift. These expenses, usually referred to as indirect or redistributable expenses, consist of services such as electric power, water, maintenance and repairs, as well as any other services that may be required. Supervision and administration expense, property taxes, depreciation of owned equipment, rental of equipment not chargeable to a specific location, and the proper share of starting costs are included in the indirect expense classification.

The following three sections of this chapter will present typical direct and indirect costs to give the reader a better understanding of the nature of these operating costs and to provide a guide for estimating operating costs.

DIRECT COSTS

Supplies—A typical list of supplies required to work a drift using track is:

Rails	Ventilation fan bag
Ties	Rock bolts
Track spikes	Drill steel
2-in. diameter air pipe	Bits
1-in. diameter water pipe	Explosives

It is possible to work out a reasonable estimate of the cost of advancing a drift even though the amount of explosives, rock bolts, steel, and bits will vary with the nature of the ground conditions. A conservative cost estimate for direct supplies would be \$22.10/ft. of advance. This estimate, based on the assumptions of (1) moderate difficulty in breaking ground and (2) purchase of all new supplies and equipment, was derived as follows:

Direct supply cost per 6 ft. of advance.

Bits (1-½ @ \$6 ea.)	\$ 9.00
Drill steel (1 @ \$20.85)	\$ 20.85
Dynamite (75 lb. @ \$43 cwt.)	\$ 32.25
Fuse (420 ft. @ 2.5¢/ft.)	\$ 10.50
Caps (30 @ 5¢ ea.)	\$ 1.50
Rails (80 lb. @ \$20.00/cwt.)	\$ 16.00
Track spikes	\$ 2.00
Track ties (3 @ \$3.00 ea.)	\$ 9.00
2-in. pipe (6 ft. @ \$1.25/ft.)	\$ 7.50
1-in. pipe (6 ft. @ 50¢/ft.)	\$ 3.00
Rock bolts (3 @ \$3.00 ea.)	\$ 9.00
Vent tube (6 ft. @ \$2/ft.)	\$ 12.00
Total for 6 ft.	\$132.60
Cost per ft.	\$ 22.10

Labor—Labor cost includes not only the amount paid to an employee for work performed but also Social Security taxes and Workers' Compensation Insurance premiums. For each dollar of wages paid, the labor cost to an employer is \$1.3138*.

Paid to employee	\$1.00
*Old Age and Survivors Insurance Social Security) 5.85% × \$1 (to \$13,200 earnings/year/person)	0.0585
*State Unemployment Tax (Montana) 3.1% × \$1 (to \$4,200 earnings/year)	0.031
*Federal Unemployment Tax	0.0058
*Industrial Accident Insurance (Montana) 21.85% × \$1 (underground rate)	0.2185
Total cost to employer	\$1.3138

Employers are subject to a Federal Unemployment Tax if they pay wages of \$1,500 or more in any calendar quarter, or had one or more employees at any time in each of 20 calendar weeks. The rate is 3.28 percent of the first \$4,200. One may take a credit against this Federal Unemployment Tax but not more than 2.7% of taxable wages for contributions that are paid into state unemployment funds. Wage costs may be increased further by paid vacations, holidays, and sick leave. In addition, employees who work more than 40 hours per week must be paid for the overtime at the rate of 1.5 times their base pay. The labor cost of 131.38 percent of wages paid does not include overtime, Federal Unemployment Tax, or vacation pay. This rate is the bare minimum for labor cost.

To estimate the direct cost to advance a drift, assume that two men are hired at \$40 each per shift. Labor cost to the company is:

Paid to employees (\$40 × 2)	\$ 80.00
Taxes and insurance (\$80 × 0.3138)	25.10
Total labor cost	\$105.10

If the workers advanced 2 feet during the shift, the labor cost per foot would be \$52.55 (\$105.10 ÷ 2). The farther the men advance during a shift, the lower will be the cost per foot. For a 4-foot advance, the cost per foot would be \$26.28; and for a 6-foot advance, the cost would be \$17.52 per foot.

Because of the incentive system in mining, men will seldom work as hard on a base wage as they will on a production bonus. For the miners to make 6 feet of advance a shift, they must usually have an incentive, a 'promise' to receive more money for this added work. Assume that a price of \$20 per foot will be paid to the miners for every foot they drive. If they make 6 feet of advance per shift, the cost to the company is \$20 × 6 × 1.3138 = \$157.65, and \$157.65 ÷ 6 = \$26.28/foot. Comparing this to the days-pay rate, we see that the incentive system cost the company more per foot, provided the crew makes 6 feet of advance, but usually the men not paid on an incentive basis will not make 6 feet of advance.

For our example, assuming 4 feet of advance per shift, the labor cost is \$26.28/foot. From our supply cost estimate, the supply cost is \$22.10/foot. The direct cost per foot of advance is \$26.28 plus \$22.10 = \$48.38. Shaft, raise, and stope costs can be estimated by the same procedure.

Skill in mining also affects the supply cost per foot of advance or per ton of ore. In the drift example, suppose that the miners drilled a 6-foot round for explosives but, when blasted, the drift advanced only 4 feet. Some of the drill steel, bits, powder, and time expended on this round did not produce results. Our supply cost would be as follows (assuming the same conditions):

Bits 1½ × \$6	\$ 9.00	Same amount is used as in a 6-ft. round.
Steel	\$20.85	
Dynamite \$43 × .75	\$32.25	
Fuse 30 × 14 ft. = 420 × 2.5¢	\$10.50	
Caps 30 @ 5¢	\$ 1.50	
Rails 20 lb./yd. $\frac{8 \text{ ft.}}{3}$ × 20 = 53½ lb.		
53⅓ × 20¢	\$10.70	

* Subject to change; be sure to use current figures in actual computations.

Track spikes (est.)	\$ 1.50
Track ties (2)	\$ 6.00
Pipe 4 ft. of 2-in. 4 × 1.25	\$ 5.00
Pipe 4 ft. of 1-in. 4 × 50¢	\$ 2.00
	\$99.30

But for 4 feet of advance

$$\frac{79.40}{4} = \$24.83$$

The supply cost increases almost 12 percent because the round, when blasted, did not break 6 feet. The labor cost would also increase, but probably not at this exact proportion. If the miners were on a bonus system of a certain fixed price per foot of advance, they would suffer the same as the company by not breaking to the bottom of their round.

INDIRECT EXPENSES

As stated earlier, indirect expenses are those that must be split over several working places. They are just as much a cost of doing business as are direct costs, but for accounting purposes they cannot be charged directly to a specific location. They must be allocated or redistributed to working places on some logical basis. The following incomplete list illustrates the type of expense that must be treated as indirect:

Indirect labor:
- Management and supervision
- Engineering and geology
- Office
- Mine maintenance
- Hoist men and cage tenders
- Level crews

Other indirect expense:
- Fuel (heating)
- Supplies
- Repairs
- Interest
- Taxes
- Insurance

From the list of indirect expenses, it can be seen that mining requires a large number of workers to support those directly engaged in ore extraction. It is easy for a company to become overburdened with indirect labor. If costs are to be kept in line, management must keep a tight control over the number of supporting workers employed.

Every mining situation is different, hence, the number of indirect workers will differ from mine to mine. Minimum requirements would be a shift boss for each shift and a mine foreman to coordinate the work of the shift bosses. Over the mine foreman would be a manager, although in small mines the foreman and manager may be the same person. An engineer and a geologist are required. If the geology is simple, perhaps one man can handle both phases of the work. The following tabulation indicates the number and kinds of supporting personnel that might be required for an operation involving seven working places with two miners at each place.

	One Shift	Two Shifts
Supporting labor:		
Hoist men	1	2
Surface men	1	2
Warehouse man) Electrician) Mechanic)	1	1
Level crews (2)	4	8
Station tenders	1	2
	8	15
Management and offices:		
Bosses	1	1
Engineer	1	1
Office	1	1
	3	3
Total	11	18

If we assume that all supporting labor receives \$36/shift, and that supervision and office help are paid at the rate of \$60 a shift, then the indirect labor cost would be:

One shift	
Supporting labor (\$36 × \$1.3138** × 8)	\$ 378.37
Supervision and office (\$60 × \$1.3138 × 3)	\$ 236.48
Total	\$ 614.85
Rounded off	\$ 600.00
Two shifts	
Supporting labor (\$36 × \$1.3138 × 15)	\$ 709.45
Supervision and office (\$60 × \$1.3138 × 4)	\$ 315.31
Total	\$1,024.76
Rounded off	\$1,000.00

The other indirect expenses are difficult to estimate. We know that a mine will consume power; in the winter there will be a cost for heating; interest and insurance will depend upon how much is invested in the mine; depreciation will depend upon the cost of machinery and equipment; and, of course, there will be repairs made and supplies used. What might these indirect costs be? It may be well to estimate them on a monthly basis. Taxes and insurance have been

**Not all personnel would cost the company this much, because the Industrial Accident rate is not as high for those who do not go underground. As there are only a few who do not go underground, the \$1.3138 figure will be used in our calculations.

calculated previously as 15 percent of the average investment.* In mining, the equipment probably would average a maximum useful life of 10 years. If the investment in mine equipment was $100,000, not including the mill, the average investment for estimating taxes and insurance is as follows:

$$0.15 \frac{(10 + 1)}{20} \times \$100{,}000 = \$8{,}250/\text{yr or}$$

$688/month

Taxes, insurance, and interest	$ 688
Estimated power bill	2,000
Estimated fuel bill	200
Estimated repairs and miscellaneous	1,000
	$3,888

Total indirect costs for our example = $3,888/

$$\text{month} = \frac{3{,}888}{25 \text{ day/mo.}} = \$156/\text{day}.$$

To be on the safe side, estimate $160 per working day. It is estimated that a second shift would increase the daily charge for indirect expenses by 60 percent because of the increased power, fuel, and supplies that would be consumed, as well as additional repairs that would be required.

Total daily expenses, including labor and other indirect expenses, are summarized as follows:

	Single shift	Double shift
Indirect labor	$600	$1,000
Other indirect expense	160	256
Total	$760	$1,256

It was stated earlier that our example assumed an operation requiring fourteen miners working in seven locations. Indirect expenses are incurred in order to support the work being done in these seven places. The easiest way to account for these indirect expenses is to apportion the total equally over the working places. Therefore, in our example, on a single-shift operation each place would be charged $109/day for indirect expenses. For a double shift, the per-place charge would be $180/day or $90/shift.

OPERATING COST SUMMARY

In our example, we have estimated that two miners will be working at a particular location and that the direct labor cost to the company for each shift will be $105.10. Direct supplies have been estimated at $22.10/foot of advance. For each location, all indirect expense will be $109/shift, or $90/shift on a two-shift operation.

The following tabulation shows estimated costs per foot of advance under each of four different conditions.

*See Chapter 5 for an explanation of average investment.

Cost estimate per foot of advance

	One shift		Two shifts	
	4 ft.	6 ft.	4 ft.	6 ft.
Direct labor	26.28	17.52	26.28	17.52
Direct supplies	22.10	22.10	22.10	22.10
Indirect expenses	27.25	18.17	22.50	15.00
Cost per foot	75.63	57.79	70.88	54.32

The difference in cost per foot is due to two factors. The first and more important is the direct labor cost. The cost of two miners is $105.10, regardless of the amount of advance they make. Obviously, the greater their advance, the lower will be the direct cost per foot. The second factor is indirect expense. Indirect expense is fixed at $760 (one-shift-per-day basis) for each shift, or $109 for each location, if there are seven locations or working places, as in our example. The greater the progress made during a single shift, the lower will be the indirect expense per foot advance. The preceding tabulation illustrates forcefully the cost savings that result from increased productivity.

From the previous examples, we can see why it is so difficult to estimate what certain work will cost. The cost is geared to production. For example, if by 'daily wage' operations the drift advances only 2 or 4 feet per shift, but the incentive or 'bonus' system produces a drift advance of 6 feet per shift, the cost is considerably reduced. Why? Because the indirect costs per foot of advance are reduced.

It is possible to estimate the cost of other mining operations, such as stoping, raising, or shaft sinking, by using some of the cost relationships developed in the preceding example. Very often, the ratio of direct labor cost to total cost is used as a basis for estimating the total cost of a particular operation. In the above example, direct labor cost ranged from 30 to 37 percent of total cost. To illustrate the application of this procedure we might take an average ratio of direct labor cost to total cost of, say, 35 percent. If two men were driving a raise, and if they made the same footage per shift as in our drift example, the calculations and cost results for the raise would be approximately the same as in the drift. The direct labor cost would represent 35 percent of total cost. Therefore, if the miners were paid $105.10 for a 4-foot advance, the total cost would be estimated at $300, or $75 per foot.

How would this procedure work out for stoping costs? These costs should be related to the number of tons of ore produced. If we assume that direct labor represents 35 percent of total cost, then total cost would be direct labor divided

Tons mined per shift	Direct labor cost	Cost per ton	Ratio of direct labor cost to total cost	Total cost per ton
10	105.10	10.51	35%	30.03
15	105.10	7.01	35%	20.03
20	105.10	5.26	35%	15.03
30	105.10	3.50	35%	10.00
40	105.10	2.63	35%	7.51
50	105.10	2.10	35%	6.00

by 0.35. To illustrate, assume that the following conditions prevail; two stope miners averaging $40 per day in wages (2 × $40 × 1.3138 = $105.10).

These figures are not standards; they merely illustrate how it is possible to estimate total costs for different mining operations. Only current operating costs are included in the above illustrations; such 'sunk' costs as development expense and surface plant are not included but would also be a part of the total cost of producing ore.

WAYS TO REDUCE COSTS

Equipment.—Any mining operation requires a considerable investment in machinery and equipment. When starting a mine, many operators tend to buy too much equipment. When this happens, funds are tied up in equipment that is not producing. These funds could be more advantageously employed in a more productive fashion. Then too, it costs money to own equipment, and the ownership of excessive equipment results in a cost for which little or no benefit is derived. If costs are to be kept to a minimum, avoid overcapitalizing. Careful initial planning can help greatly in reducing starting costs.

When equipment is purchased, certain spare parts are needed so that, in the event of a breakdown, repairs may be made without loss of time. What spare parts should be carried should be carefully determined. A savings can sometimes be realized by purchasing all machinery from one manufacturer, so the parts for the machines may be interchangeable. For example, if five air-leg drills are required and all are of one model and are made by the same manufacturer, only parts for that one type of machine need be kept on hand.

Supplies.—The supplies necessary to keep the mine going should be studied thoroughly. Great savings in inventory can result from proper purchasing. The length of time required to replace supply items should determine the size of the inventory one should carry. For example, if explosives can always be obtained within a week after ordering, then it should not be necessary to reorder until the stock on hand has dropped to a two-weeks supply. The extra week's supply is merely a safety margin against completely exhausting the supply. If excess explosives are kept on hand, some may be wasted by spoilage and careless usage. This same principle can be applied to all supply items.

Labor costs.—There are theoretically two ways to reduce labor costs. They are to lower wages or to increase production per man. In this day, lowering wages is out of the question. Increasing production, then, is the only practical procedure. This may mean supplying the men with new, more, and better equipment. It may mean establishing an incentive or bonus system so the men may receive part of the savings that result from increased production. When setting the prices for bonuses or production incentives, one must be careful that the terms will be easily understood. The following check list should be applied to any proposed incentive system:

1. Will more production reduce costs?
2. Is the system simple to understand?
3. Is it fair?
4. Are the supervisors aware of all parts of the proposed system?
5. Is it workable?
6. Are there any expensive 'leaks' in the system?

An incentive system that does not fulfill these requirements may be useless.

Mining Records. — Costs are inevitable if a mine is to operate. The proper recording of costs is essential to meet the requirements of federal and state laws. More important, however, costs should be recorded properly so that the mine operator will be in a position to determine the efficiency of his operations. Too many operators regard accounting as a necessary evil—a job that must be done in order to meet governmental requirements. This point of view is unfortunate, because accounting can give an operator an insight into his business that he cannot get by mere observation. Accounting should be regarded as a valuable aid to mine management.

Accounting for mines will be discussed in general terms in a later chapter.

CHAPTER 7 — OTHER COSTS OF DOING BUSINESS

By KOEHLER S. STOUT

INTRODUCTION

In the calculations of production costs (Chapter 6), employment insurance and property taxes were treated as fixed costs, because they are relatively constant and are incurred by any kind of business. Certain other kinds of insurance and taxes, notably state and federal income taxes, must be treated as variable costs, and others are unique to the mining industry. These costs greatly influence the profit expectations from mining and must be considered in evaluating a mineral deposit.

In recent years, environmental protection has become very important, especially in the mineral industry. This has increased the cost of mining. For example, it is now necessary on the U.S. forest lands and on all lands where mining is to take place in some states (e.g., Montana) to restore mined land to as near an original contour and use as possible. To ensure that restoration and rehabilitation take place, some agencies require the posting of bonds. Bonding is an initial expense of any planned operation, and the rehabilitation cost must be carried by the production of mineral (see Chapter 12 for additional details).

Insurance will be reviewed in some detail in this chapter, because laws require that certain types must be carried by all employers. Montana insurance rates will be followed in this chapter for examples, but for other areas check the rates in that state. They may be (and probably are) different from the examples used here.

Although some taxes were treated as fixed costs in the previous chapter, Net Proceeds Tax, Metal Mines License Tax, Corporation Tax, and Income Tax were not included in this cost estimate. These taxes are imposed on production and profits. Although Montana and some other states have these forms of taxes, still other states impose an ad valorem tax similar to a property tax. Check the tax structure in your state to determine the influence of taxes on your operation, because different states use different methods and rates.

Not to be overlooked when evaluating a mineral property for profit are the costs of the safety requirements of the Mine Enforcement Safety Agency (MESA) and other federal or state regulatory bodies. The value of doing work in a safe manner cannot be disputed, but the initial cost of meeting these safety requirements may be substantial and cannot be disregarded in evaluation.

In dealing with the physical or material aspects of mining we can be reasonably certain that what is true today will be true tomorrow—the hoist that raised 100 tons of rock yesterday can raise 100 tons of rock today and tomorrow and the next day. The same is by no means true of the intangible factors involving human beings. Therefore, it is essential to bear in mind that what we write today concerning tax laws, insurance rates, and similar factors affecting the mining industry may be invalidated by tomorrow's legislative act, administrative ruling, or court decision.

RECLAMATION OF MINING LAND

Because most of these laws or rules and regulations are relatively new, it is difficult to assess their cost until some actual experience has been gained by operators. Violators are subject to fines and forced suspension of their operations, however, so one must be cognizant of their existence and implications. These laws and regulations will probably be subject to changes, alterations, or modifications because of their untested newness. An operator must check all current reclamation requirements in the state in which he is operating in order to evaluate the effect on the cost of any contemplated mining venture. Justifications for the existence of these laws are given in the following quotations from the Montana law.

50-1201. Legislative observations and finding. The extraction of mineral by mining is a basic and essential activity making an important contribution to the economy of the state and the nation. At the same time, proper reclamation of mined land and former exploration areas not brought to mining stage is necessary to prevent undesirable land and surface water conditions detrimental to the general welfare, health, safety, ecology, and property rights of the citizens of the state. Mining and exploration for minerals takes place in diverse areas where geological, topographical, climatic, biological and sociological conditions are significantly different, and reclamation specifications must vary accordingly. It is not practical to extract minerals or explore for minerals required by our society without disturbing the surface or substance of the earth and without producing waste materials, and the very character of many types of mining operations precludes complete restoration of the land to its original condition. The legislature finds that land reclamation as provided in this act will allow exploration for and mining of valuable minerals while adequately providing for the subsequent beneficial use of the lands to be reclaimed.

50-1202. Purpose of act. The purposes of this act are to provide: (1) that the usefulness, productivity and scenic values of all lands and surface waters involved in mining and mining exploration within the boundaries and lawful jurisdiction of the state will receive the greatest reasonable degree of protection and reclamation to beneficial use; (ii) authority for co-operation between private and governmental entities in carrying this act into effect; (iii) for the recognition of the recreational and aesthetic values of land as a benefit to the state of Montana; and (iv) priorities and values to the aesthetics of our landscape, waters and ground cover. Although both the need for and the practicability of reclamation will control the type and degree of reclamation in any specific instance, the basic objective will be to establish, on a continuing basis, the vegetative cover, soil stability, water condition and safety condition appropriate to any proposed subsequent use of the area.

The United States Forest Service has established rules and regulations for prospecting and mining on the national forest lands subject to the United States mining laws of May 10, 1872, as amended. Copies of these rules and regulations can be obtained from the district forest ranger who has jurisdiction over the claim area if the claim is on forest lands. They are discussed in more detail in Chapter 12. These Forest Service rules do not apply to federal land managed by the U.S. Bureau of Land Management, a branch of the United States Department of the Interior, but at the time of this writing, the Bureau has announced that it will publish and enforce rules similar to those of the U.S. Forest Service. If and when they go into effect, copies will undoubtedly be available from any Bureau of Land Management office. Although the rules apply only to unpatented mining claims, they will undoubtedly have some influence on patented claims when it comes to obtaining rights-of-way and waste-disposal areas over neighboring nonpatented ground.

State laws, however, generally apply to all mining whether it is conducted on public domain or private ownership of any type and whether the claims are patented or unpatented. If one is operating in a state where reclamation laws are in effect, then compliance with state laws is necessary. It is to be hoped that when one satisfies the state reclamation requirements, the federal requirements will also be satisfied, or vice versa, but because of the newness of these laws and regulations, this point is not clearly established. During this transition period the miner must consult both federal and state agencies if he has unpatented mining claims on U.S. forest lands.

The usual requirements for a permit consist of notifying the agency of your intent to work a mining claim, your plan of operation, the names and addresses of claimants and operators, and their lessees, assigns, or designees; exact location; extent of the proposed disturbance; and a description and timetable of the work.

Before any work can commence, these plans must be approved by the state or federal agency. When permission is given, the approved plan must be followed. If it becomes necessary to deviate from these approved plans, permission for any deviation must be received from the agency before any changes from the original plan can be made.

If the operator is not complying with the approved plans, the agency has the right of inspection and the power to suspend the operations after a notice of noncompliance has been served on the operator. To ensure that the mine operator meets all obligations, it is necessary for him to post a money bond, the amount of which is determined by the agency. Bonding requirements vary from state to state and job to job, so local laws must be checked, but most bonding requirements are similar to those prescribed by the U.S. Forest Service as discussed in more detail in Chapter 12.

INSURANCE

INTRODUCTION

Insurance is protection against loss. The insurer agrees to compensate, pay, or protect the insured in case of loss or liability of a specific subject. All of this must be under the terms of the insurance contract or policy. For this protection, the insured must not only pay the premiums, but he must abide by the provisions of the policy. The premium payment amount is determined by the size and kind of risk. Most of you are familiar with the following types of insurance: life, fire, car collision, and car liability. Most businessmen carry property loss, inventory, and liability insurance. In addition, the businessman must carry certain insurance if he hires men to work. The law says so. Even if a man works alone, or is self-employed, he should be covered by certain types of insurance. A mine operator should, and in some cases must, be covered by insurance. Hence, this subject is important to him.

There are many different kinds of insurance. In business insurance there are two broad divisions: (1) the insured is paid money for some loss that he has suffered, such as the usual property insurance, fire, and flood; and (2) the insurer takes the place of the insured and pays to an injured third party the amount of money due him by some fault of the insured. The insured is thus relieved of any financial obligations if the amount is within the limits of his policy. This type is known as liability insurance. Both divisions are important to the mine operator. Life insurance also may be important, especially for partners or owners of a small corporation.

If mine machinery is new and valuable, property insurance should be carried. Thus, if a calamity strikes, the insurer will either provide equipment or pay for the loss, and the mine can continue operation. Liability insurance may be a sound purchase. This will help to protect you in a lawsuit, which may arise from either your own or your employees' actions. A lawsuit that is judged against you or the mine may ruin you or your company if you are not insured. Automobiles, trucks, or other motorized equipment should be covered by appropriate insurance.

Federal and state laws require the employer to carry certain types of insurance. These are: (1) Social Security, (2) Industrial Accident, and (3) Unemployment, both federal and state.

Social Security is sometimes called a tax rather than an insurance, but its objectives are similar to those of certain types of insurance policies. Thus, it provides the employee with an income when he retires or it will care for his family if he is killed. Industrial accident is a form of insurance that indemnifies the worker if he is injured. Unemployment insurance guarantees the employee specified payments for a certain length of time if he is unemployed.

SOCIAL SECURITY

The Federal Social Security Act provides for two systems of social insurance.

1. The most important is the Old-Age and Survivors Insurance. Under this are four benefits:
   a. Retirement plans for employees when the employee reaches 65 (62, if a woman), for his wife at 62, or for his wife at any age if she is caring for either the employee's children under 18 years of age or for a totally disabled child at any age who was disabled before the age of 18.
   b. Disability insurance benefits to the employee and to eligible dependents if the employee is permanently or semi-permanently disabled.
   c. Survivors insurance payments to dependents if the employee dies at any age.
   d. Medicare coverage to persons 65 and over, but in some cases to persons under 65 with disabilities.
2. Unemployment insurance is also a part of this federal law, but usually the state administers this law. The federal government provides some of the state's operating costs. The 0.58% federal unemployment tax mentioned in previous chapters provides the revenue for this cost. Unemployment will be discussed more in the next section.

Financing of this program is described in a booklet, obtainable from your Social Security office, titled Your Social Security, DHEW Publication No. (SSA) 74-10035 as follows:

Contribution rates

If you're employed, you and your employer each pay an equal share of social security contributions. If you're self-employed, you pay contributions for retirement, survivors, and disability insurance at a somewhat lower rate than the combined rate for an employee and his employer. The hospital insurance contribution rate is the same for the employer, the employee, and the self-employed person.

As long as you have earnings that are covered by the law, you continue to pay contributions regardless of your age and even if you are receiving social security benefits.

Through 1977 employees and employers each pay 5.85 percent on the employee's wages. The total rate for self-employed people is 7.90 percent. The rates include .90 percent for hospital insurance under Medicare. The maximum amount of earnings that can count for social security purposes and on which you pay social security contributions was $13,200 in 1974.

Future rate increases are scheduled. In 1978 the employee and employer will each pay 6.05 percent. The rate for each will go to 6.30 percent in 1981 and 6.45 percent in 1986. The self-employed rate goes to 8.10 percent in 1978; to 8.35 percent in 1981; and to 8.50 percent in 1986. The hospital insurance part of the rate will be 1.10 percent in 1978; 1.35 percent in 1981; and 1.50 percent in 1986.

Funds not required for current benefit payments and expenses are invested in interest-bearing U.S. Government securities.

The Government's share of the cost for supplementary medical insurance and certain other social security costs come from general revenues of the U.S. Treasury, not from Social Security contributions.

For information on Social Security, consult the nearest Social Security Administration Office in your area. It is under the U.S. Department of Health, Education, and Welfare. The benefits from social security will accrue, regardless of your financial status, although after you retire you are limited in the amount you can earn and still receive full payments. After age 72 you can earn any amount and still receive full benefits.

After deductions have been made on $13,200 in one year, neither the employer nor the employee contributes any more to the fund during that year. (This limit is subject to change, however.)

UNEMPLOYMENT INSURANCE

Unemployment insurance is required for most employment in virtually all states and by the federal government. There are a few exemptions to this blanket requirement, notably in casual, domestic, and some agricultural work, but the exemptions are gradually being reduced. Mining is an insurable occupation in every state, so the operator must contribute to the unemployment fund for each employee. The employee does not contribute to the fund; the employer pays all. For example, in 1974, the maximum rate in Montana was 3.1 percent to a maximum earning of $4,200 by the employee, and the federal rate is 0.58 percent of the employee's wages. The rate differs in other states, but this insurance is a substantial cost to the employer and must be considered when estimating operating costs.

WORKERS' COMPENSATION INSURANCE

Workers' Compensation insurance is a major item in mining employment costs, especially for underground workmen. The following discussion applies to Montana law, but most states have similar laws, and the principles discussed here would be at least in part applicable in most states.

Industrial accident insurance compensates the employee if he is injured while at work. The Workers' Compensation Board (hereinafter called the Board) administers the provisions of the Workers' Compensation Act (hereinafter called the Act). The Act is a series of statutes that define the rights, remedies, benefits, and courses of action for both the employer and employee. Under common law provisions relating to industrial accident, the employer was liable for injuries to his employees, but the common law recognized three forms of defense for the employer. These were:

1. If contributory negligence on the part of the employee, the employer was not liable.
2. If the carelessness of a fellow employee caused the accident, the employer was not liable.
3. The employee assumed the risk of injury, thereby releasing the employer.

If the employer could prove any of these three in a court of law, he was not liable. The employee would have to press charges in a court of law. Many employees could not afford it. Under this system, inequities arose because the employee could seldom recover from his employer.

To remedy this situation, most states, including Montana, passed Workers' Compensation Acts. These statutes forbid any employer to use the three common defenses given above in a court of law, but he can charge willful negligence. Willful, as defined by the courts, means that the employee has a wanton and reckless attitude toward breaking accepted and reasonable rules of safety. If an employee deliberately injures himself, it would be judged willful negligence. Employers who elect not to come under the Workers' Compensation Act, and employers in industry not covered by the Act, are not bound by the above ruling. These statutes give the employer protection if he elects to come under the Act. By law, he has no obligations to the employee except as defined by the Act, that is, if the employee recovers damages under the provisions of the Act, he cannot later sue the employer for more. There may be some exceptions to this rule.

Generally both the employee and employer may choose whether they want to be bound by the Act or not. If the employer is not bound, the employee working for him is not bound either. In Montana, however, mining is regarded as a hazardous occupation and the employer must abide by the Workers' Compensation Act. He has no choice. An employee, if employed in a hazardous occupation such as mining, may choose whether or not he will be covered under the terms of the Act. To elect **not** to come under the Act, the employee must notify both the Board and the employer in writing on a form prescribed by the Board. If the employee does not so notify the employer and Board, he is bound under the provisions of the Act. The employee, if not bound, can sue the employer for an injury, and in the amount of recovery he is not bound by the limits set forth in the Act, but if the employer is covered by the Act, he can use the common law defenses in the suit. These defenses often give the employer an advantage in a lawsuit.

The Act states the amount to be paid for different injuries if both the employee and employer are under its terms. It defines the amount to be paid for total disability, partial disability, or the amount of compensation to be paid to beneficiaries in case of death. It also defines injuries and the conditions under which benefits are to be paid. This Act is defined in Title 92 of the Revised Codes of Montana, 1947.

There are three compensation plans in Montana that an employer may elect, but to select any of the three he must meet the requirements of the Board. In Plan Number 1 the employer carries his own insurance under the provisions of the Act. He must show proof, satisfactory to the Board, that he is financially able to pay all the obligations and benefits that may arise under the Act. In addition, the Board may require the employer to post security to ensure that the employees receive the benefits.

Compensation Plan Number 2 provides that the employer may insure his liability to pay the compensation and benefits of the Act with an independent authorized insurance agency. The insurance company must have the approval of the Board. The policy, too, must meet the approval of the Board in terms of coverage to the employee. This plan may be advantageous if the plant has been operating for considerable time with a good safety record. The premiums may be lower than under the provisions of Plan Number 3.

In Plan Number 3, the Industrial Accident Board is the insurer. To become insured under Plan Number 3, the employer must receive a policy from the Industrial Accident Board. He pays an amount equal to a certain percent of the employees' payroll wage as a premium. To ensure coverage, the employer is required to post security with the Board, the amount to be determined by the Board. Thereafter, the employer must send in a payroll record and the Board will bill the employer for the amount due. Most new companies will elect to come under Plan Number 3. They seldom have the financial requirements for Plan Number 1. Insurance companies will not quote a lower rate until the safety record at the plant has been established. The rates one must pay in Plan Number 3 are determined and set by the Board.

The three types of insurance just discussed, social security, unemployment, and industrial accident, are required by law. Therefore, they are a real cost of operation. Their effect in the cost of operation must be considered when making estimates. If not, the estimates will be in error.

Although not an insurance, the minimum wage laws and the laws pertaining to overtime must be obeyed. For work in excess of 40 hours per week, the hourly rate must be increased 1.5 times. This is an added cost of operation, but in some circumstances this expense may be justified, especially if employees are scarce or if a job must be done without delay.

PUBLIC LIABILITY INSURANCE

One of the best ways to get adequate insurance protection is to select a good reliable insurance agent or broker. The agent should not only take an interest in his client's business but also understand it so that he will recognize what the business problems are. Only with this knowledge can he give the insured the best coverage for the least money. To cover every possible contingency with insurance would be too expensive. You, as a mine operator, must assume some of the risks. You are the one who must make the choice. You can, by proper management, eliminate many of the risks. For example—buildings made from fireproof material will eliminate or at least greatly reduce the fire hazard. Their initial cost may not be much greater than that of buildings made from flammable material. An efficient safety program will reduce many industrial hazards.

Liability insurance covers you or your organization in case of an injury to someone other than an employee. For example, if someone comes on your property and is injured because of some negligence of yours, you are liable not only for his injuries but possibly for loss of his future earnings. A judgment against you or your company may adversely affect your financial condition, unless you are covered by liability insurance.

SUMMARY

If you are in business, the Federal Government will, for tax purposes, allow some insurance as a legitimate business deduction. The Internal Revenue Service allows deduction of only insurance premiums that are ordinary and necessary in the conduct of your business. The following premiums have been allowed as deductions in many cases, because they are regarded as legitimate business expenses:

- Fire, theft, flood insurance
- Workers' Compensation insurance
- Merchandise and inventory insurance
- Public liability insurance
- Employee's liability insurance
- Employee's group hospitalization and medical insurance
- State unemployment insurance
- Group life insurance (must meet certain requirements)
- Automobile and other vehicle insurance
- Credit insurance
- Overhead insurance
- Use and occupancy insurance and business income
- Employee performance bonds
- Expense for required bonds
- Personal life insurance (on officers and employees of corporations in certain cases only).

TAXES

INTRODUCTION

Taxes are a real part of operating expense. Therefore, they must be considered when estimating the potential profit of an ore body. What are taxes? They are a ratable portion of the production from the mine and the labor of the individual that are demanded by the national, state, or local governing body for support of government. These taxes may be large, especially if the mine is profitable.

There are many forms of taxes. The ones with which we are most familiar from our personal lives are general property tax, income tax, and estate tax. These same taxes apply to incomes of corporations or other mining organizations, although not always directly. Income from minerals may also be subject to severance and mine-license taxes. All of these taxes fall into two general categories. One applies to material things already owned or about to be owned (property, license, estate tax). The other applies to the amount one produces and the returns from this production (income and severance taxes). Property, whether it is producing or not, is always subject to the first type, but the second type applies to a property only if it is producing.

Property tax on real and personal property is assessed by the cities, counties, and states. Real property is land and generally whatever is erected, growing on, or otherwise affixed to it. Personal property, generally, is any other property. These property taxes are sometimes called **ad valorem** taxes, meaning merely a tax or duty upon the value of the thing.

Some states tax the net proceeds of all mines and mineral producers. This is a production tax

(tax on profits) because its amount depends on the value of the production minus the allowable cost of operation. In addition to the **net proceeds tax,** there may be a **metal mines license tax.** This tax is based on the gross products of the mine rather than the profit.

Because mining property can be transferred by sale, descent, or gift, all taxes on these transfers of property apply to mining properties. The amount of these taxes is determined by the value of the mine. As we have seen, valuation of a mine is most difficult.

Income tax is a tax on profits. The federal government and some states tax profits. Not only are incomes of individuals taxed, but the federal government taxes incomes of corporations. Montana has a **corporation tax,** which is somewhat similar to an income tax. Even after the incomes of corporations are subject to income tax, dividends from corporations to stockholders must be included in an individual's income and are again subject to **personal income tax** by both the federal and state governments. The tax law currently allows a certain deduction in reporting income from dividends in a corporation.

PROPERTY TAX

Virtually all states tax equipment used in mining operations. This is called a personal property tax, and the methods and rates of taxing differ widely. For example, in Montana in 1974, the tax base on mining machinery was 30 percent of its true and full value.

Taxing the mineral wealth of mines has been a very perplexing problem in all mining states. The true value of a mine can seldom be accurately known until it is worked out, but many situations necessitate estimation of the value. Although the system contains many drawbacks, the fair market value is often used. In the case of Bader v. United States (SD 111 1959) 172 F Supp. 833,836, the court defined "fair market value" as:

" . . . the price at which property would change hands between a willing buyer and a willing seller, neither of whom is under any compulsion to buy or sell and both of whom are reasonably well informed as to the facts having a bearing on value."

The value is usually set at the time of the sale or transfer, and later ore findings are not usually regarded as part of the original fair market value.

This definition or basis, although used in some states for tax purposes, is not completely satisfactory because later ore findings may greatly change the value of the property, or conversely, development work may show the deposit to have been overvalued. Downward adjustment of tax rates is a slow and perplexing process. Almost every mining state has its own method of taxation, and there is little similarity of methods between the states.

The general methods of taxation of mines consist of the following:

a. Mines are treated as ordinary property and taxed as such. This is frequently called an ad valorem tax.
b. The severed product from the mine is taxed as personal property.
c. Some form of license, occupation, or production tax is imposed on the mine.
d. A combination of the three systems.

The following mining states have some form of ad valorem taxation: Arkansas, Arizona, California, Colorado, Idaho, Minnesota, Montana, New Mexico, Nevada, Pennsylvania, Utah, West Virginia, and Wyoming. Various systems are used for determining the value of the property for taxation. The true, cash, or fair market value is generally used in Arkansas, Arizona, Minnesota, Pennsylvania, and West Virginia. California uses a system based on a proportion of the value. Colorado, New Mexico, and Nevada assess non-producing mines according to their value. Idaho and Montana tax on the basis of the price paid to the U.S. Government, plus a tax on the net proceeds of production. Utah charges a flat rate per acre plus a tax on net proceeds of producing mines, and a tax on 30 percent of reasonable fair cash value of all other mines. Oklahoma and Wyoming tax on gross value of production rather than on an ad valorem basis.

In addition to the above taxes, Arkansas, Arizona, Idaho, Minnesota, Montana, and Utah apply some form of license or occupation tax. Arizona, Colorado, and Utah have either some form of taxation or no prohibition against taxation of unpatented mining claims. Unpatented mining claims are exempt from taxation in Idaho and Montana, although production from unpatented mines is taxed. Statutes specifically deal with production or proceeds from unpatented mining claims in New Mexico, Nevada, and Wyoming.

As one can see, the tax picture is complicated for mine taxation. One must check the taxation statutes and rules in the state where the mine is located to estimate the tax burden on the property.

The interests of the lessee and lessor may be important in determining the responsibility for each party's tax liability. In Montana, the following situation exists on the net proceeds tax, which constitutes a lien on the real and personal property of the mine operator. The lessor or royalty holder of the mine is subject to the payment of the net proceeds tax whether the mine operator makes or loses money on his part of the operation.* If the mine operator states that he will pay all taxes on the property, which includes the net proceeds tax of the mine owner, he is subject to the tax that the mine owner must pay on his

*Montana Supreme Court Decision, New Silver Bell Mining Co. v. County of Lewis and Clark, 284, Pacific Reporter 2d ed., 1012, 1019.

interest. Thus, if the mine loses money through legitimate operations, the lessee would still be liable for taxes on the royalty interest.

If the state does not have an income tax for corporations, it may have a corporation license tax similar to that of Montana. A Montana corporation, unless it can qualify as a small business, must pay a minimum fee of $50 plus 6¾ percent of the net income.

OTHER TAXES

The federal government and most states tax property when it is transferred at the time of death or by way of gift. As a rule, these taxes are levied on the fair market value at the time of death or at the time of transfer. Normally there are some deductions allowed from the fair market value. The basis of taxation is on the final result after deductions. These tax rates are graduated or scaled depending upon the value of the estate. For estates of larger value, the tax percentage rate is higher, somewhat similar to the personal income tax scale. The big problem, of course, is to determine the value of a mining property. Negotiations with the taxing authorities in an attempt to set a fair value on the property are often tried. If the mine is valuable, much time may be spent in determining this value.

The taxes just discussed (gift and inheritance) are usually not regarded as a part of the normal cost of operation of the mine. Therefore, they can be neglected in evaluating the potential worth of a mine. Of course, if one is left a mining property either by will or by gift, then he is much concerned about these taxes. The advice of competent tax authorities is worthwhile. They may be able to save you money on these taxes.

INCOME TAX

The federal government and most states impose taxes on the income of persons. If ore produced from a mine in any one year yields a taxable income, taxes must be paid on this income, either through individual or corporate taxation. The individual's personal income is subject to both state and federal tax.

Because most of us pay state and federal income tax, this discussion will not concern itself with personal income tax. But if your private income or some part of your income is from ownership, in whole or in part, of ore production, either as a mine operator or by holding lessor's interest, you can deduct a depletion allowance.

Depletion is the removal of ore from the deposit; the reserve is thereby depleted and eventually it is exhausted. Contrary to some popular belief, ore deposits are not free for the taking. The acquisition of clear title to a deposit involves expenditure of money. The amount so spent, divided by the number of tons of recoverable ore acquired, is the cost per ton, or unit cost. It may be a small fraction of a cent, or it may be several dollars. This cost is that incurred in obtaining title to the ore in place—it does not include any of the development or operating expense—and if no ore is ever mined, the entire amount is lost. Only by selling the ore can the cost of the ore be recovered. Deduction of the cost of the ore from the selling price is the logical basis for the depletion allowance. Thus there can be no reasonable objection to the principle of the depletion allowance.

The method sketched above is known as the **cost depletion** method of accounting, and is the logical method for an operator to use in his own accounting, if at all possible, even though in computing his income tax he uses the alternative method of percentage depletion (to be discussed subsequently). It requires a knowledge of only two figures, the amount spent to obtain title to the ore and the number of tons of recoverable ore. Although the latter cannot be known exactly until the mine is exhausted, nevertheless, the operator's most realistic estimate will serve as a starting point, and it is accepted by the Internal Revenue Service if it seems reasonable.

As mining progresses, revision of the figures probably will be necessary. Conceivably, the cost could be increased, for example, if it were necessary to file suit to quiet title. Almost certainly the estimate of recoverable reserves will be revised, possibly several times. Whenever either figure is changed, the amount not already written off is divided by the remaining recoverable tonnage to obtain a revised unit cost, which is applied to all ore mined thereafter, unless and until further revision is necessary.

Use of the cost depletion method of accounting gives the operator a true picture of his profit or loss, provided his estimate of reserves is reasonably near correct. Occasional revision of the figures is a minor inconvenience, in comparison to that advantage. In computation of income taxes, cost depletion is deductible in full, regardless of the profit or loss for the year, which is not true of percentage depletion.

The Congress of the United States has recognized the complexities involved in computing cost depletion in determining the amount of income tax owed. Partly to alleviate this situation, partly to encourage discovery and development of mineral deposits, and possibly for other reasons, the income tax laws provide for an alternative method, known as percentage depletion, for determining the amount that can be deducted as a depletion allowance.

In computing income taxes, the **percentage depletion** allowance is a fixed percent of the gross income from the property during the tax year. The percent, or rate, differs for different minerals. The allowable deduction, unlike that for cost depletion, is limited to 50 percent of the taxable income computed without deduction for depletion.

Rents and royalties paid to the lessor must be excluded from the gross sales by the lessee or operator when computing percentage depletion.

The lessor or property holder can deduct percentage depletion from royalties received for ore mined but cannot claim depletion on ordinary rent on the property. Depletion can be claimed only on the income from a wasting asset.

The following percentage depletion rates are applicable to the minerals listed.

Percentage depletion rates from Federal Tax Reporter

.015 percentage depletion rates under Tax Reform Act of 1969. — Effective for taxable years beginning after October 9, 1969, the percentage depletion rates are reduced as follows:

Depletable resource

	Old rate %	New rate %
Oil and gas	27½	22
Sulphur and uranium and a series of minerals if from deposits in the U.S.	23	22
Gold, silver, oil shale, copper, and iron ore if from deposits in U.S.	15	15
Remaining minerals presently at 15 percent	15	14
Asbestos, coal, sodium chloride, etc.	10	10
Clay and shale used for sewer pipe or brick and clay, shale and slate used for lightweight aggregate	7½	7½
Gravel, sand, and other items now at 5 percent	5	5

As indicated in the above chart, gold, silver, oil shale, copper, and iron ore remain at the 15% rate for domestic production. The extraction of other minerals from foreign operations for taxable years beginning after October 9, 1969, is depletable at a 14% rate, unless they are used or sold for use by a mine owner or operator as riprap, ballast, etc., in which case they would be subject to a 5% rate.

Presented below is a table showing all the percentage depletion rates that are effective under the Tax Reform Act of 1969.

22% Depletion

Gas
Oil
Sulphur
Uranium

If from deposits in United States

Anorthosite
Asbestos
Bauxite
Block steatite talc
Celestite
Chromite
Clay
Kyanite
Laterite
Mica
Nephilite syenite (to the extent that alumina and aluminum compounds are extracted therefrom)
Olivine
Corundum
Fluorspar
Graphite
Ilmenite
Quartz crystals (radio grade)
Rutile
Zircon

Ores of the following metals

Antimony
Beryllium
Bismuth
Cadmium
Cobalt
Columbium
Lead
Lithium
Manganese
Mercury
Molybdenum
Nickel
Platinum
Platinum group metals
Tantalum
Thorium
Tin
Titanium
Tungsten
Vanadium
Zinc

15% Depletion

If from deposits within the United States

Copper
Gold
Iron
Oil shale
Silver

14% Depletion

Metals (If not covered in the 22% or 15% rates above)
Rock asphalt
Vermiculite

If the 22% rate above, the 7½% rate below, or the 5% rate for clay used or sold for use in the manufacture of drainage and roofing tile, flower pots, and kindred products does not apply, then the following are subject to the 14% rate:

Ball clay
Bentonite
China clay
Clay used or sold for purposes dependent on its refractory properties.
Sagger clay

All other minerals, including but not limited to the following:

Aplite
Barite
Borax
Calcium carbonates
Diatomaceous earth
Dolomite
Feldspar
Fuller's earth
Garnet
Gilsonite
Granite
Limestone
Magnesite
Magnesium carbonates
Marble
Mollusk shells (including clam or oyster shells)
Phosphate rock
Potash
Quartzite
Slate
Soapstone
Stone (dimension or ornamental)
Theonardite
Tripoli
Trona

And, if from deposits outside the United States:

Bauxite
Flake graphite
Fluorspar
Lepidolite
Mica
Spodumene
Talc (including pyrophyllite)

When any of the above minerals, subject to the 14% rate, are used or sold for use by a mine owner or operator as riprap, ballast, road material, rubble, concrete aggregate, or for similar purposes, then a 5% rate applies, except for slate sold or used as sintered or burned lightweight aggregate unless these minerals, used as riprap, etc., are sold on a bid in direct competition with a mineral in the 14% category, in which case the 14% rate applies.

10% Depletion

Asbestos (if from deposits outside the United States)	Lignite
Brucite	Perlite
Coal	Sodium chloride
	Wollastonite

7½% Depletion

Clay and shale (if used or sold for use in manufacture of sewer pipe or brick)	Clay, shale, and slate. (if used or sold for use as sintered or burned lightweight aggregate)

5% Depletion

Clay (if used or sold for use in the manufacture of drainage and roofing tile, flower pots, and kindred products)	Pumice
	Scoria
	Sand
	Shale (except oil shale)
	Stone (except that used as dimension or ornamental stone)

If from brine wells

Bromine	Magnesium chloride
Calcium chloride	

Percentage depletion is allowed on minerals (other than sodium chloride) extracted from brines pumped from the Great Salt Lake and other saline perennial lakes within the United States at the applicable percentage depletion rate for the particular mineral extracted.

Saline lake.—As indicated above for taxable years beginning after October 9, 1969, a taxpayer is entitled to percentage depletion on minerals (other than sodium chloride) extracted from brines pumped from the Great Salt Lake and other saline perennial lakes within the United States. The specified percentage depletion rate for the particular mineral extracted is applicable. For purposes of determining the percentage depletion cutoff point, the extraction of the minerals from the brine is regarded as an ordinary treatment process but further processing or refining is not.

There is much controversy in Congress about the depletion allowance in our United States tax laws, and some lawmakers want to do away with it completely. They think that it is a tax loophole that should be permanently closed. Others think that it is a needed incentive to the search for mineral products. Undoubtedly, there will be some changes in depletion allowances in the next few years, so it would be wise to attempt to keep current on the depletion laws and allowances. The nearest office of the Internal Revenue Service or your accountant should be able to provide this information.

The **depreciation** allowance is the amount deducted from gross receipts each year to offset the reduction in value of equipment as a result of wear and obsolescence during the year. The yearly decrease in value of a car or truck can be estimated fairly accurately, as there is an active market in used motor vehicles, and the salvage value is the trade-in price received when the vehicle is replaced. Estimation of the annual depreciation and the salvage value of other equipment is less precise; equipment installed at very remote mines may have no salvage value. The objective of the depreciation allowance is to permit recovery of all equipment costs, minus salvage, by the time the mine is exhausted.

For the small-mine operator it is advantageous to maintain a separate record of each item of equipment, as he can then readily see whether any item is wearing out much sooner or lasting much longer than expected. Such item-by-item depreciation accounting is acceptable to the Internal Revenue Service. The record for each piece of equipment should show whether the item was new or used, the purchase price, the probable life (which determines the rate of depreciation), the annual depreciation, and the cumulative amount deducted in prior years. When the cumulative depreciation already claimed equals the purchase price, no further deduction is allowable, and any salvage value received thereafter must be treated as income. For equipment bought during the tax year, the depreciation allowance is computed only for a fraction of a year.

No single rate of depreciation is universally applicable to a particular kind of machine, such as a crusher. One operator may be crushing extremely hard ore continuously at the full capacity of the crusher, whereas another may be crushing softer material, and only periodically. One operator may replace equipment whenever he thinks that maintenance cost is excessive, whereas another may keep equipment in service as long as it will hold together. Therefore the Revenue Service will accept an estimate of a shorter than average life for a piece of equipment if the 'facts and circumstances' justify it.

The taxpayer is not required to use item-by-item accounting. He may prefer to use group, classified, or composite accounts. For example, all drilling machines may be carried in a single account. This procedure tends to average out the difference in performance of individual machines. The shorter-than-average life of a machine subjected to abuse is offset by the longer-than-average life of a machine used only intermittently.

Virtually complete consolidation of equipment accounts is permitted (but not required) under the depreciation guidelines adopted by the Internal Revenue Service for use in computing depreciation allowance for tax years ending after 1962. Under these guidelines, office equipment is allowed a life of 10 years, automobiles 3 years, light trucks 4 years, heavy trucks and trailers 6 years, land improvements 20 years, and mining equipment 10 years; these rates are allowed without question for the first three years. If the taxpayer shows that his equipment cannot be expected to last the designated length of time, however, he can use whatever shorter life is justified, but his actual practice in replacing equipment must conform closely to the life-expectancy schedule adopted.

An added incentive to modernization of equipment is the additional **first-year depreciation.** On equipment placed in operation during a given tax year and having an expected life of 6 years or more, the taxpayer may claim 20 percent first-year depreciation. Additional ordinary depreciation is computed on the remaining 80 percent for the appropriate fractional part of the year in which the equipment is put in operation, and for subsequent years. The items on which first-year depreciation is claimed must be specifically identified. The total amount of first-year depreciation that can be claimed in any one tax year is limited to $10,000, or to $20,000 on a joint return filed by husband and wife.

It is the operator's responsibility to estimate the expected life (and consequently the rate of depreciation) as best he can. If he overestimates, he may never recover all his costs; his profit will be less than expected. Allowable depreciation that is not claimed in the year in which it is incurred is lost, as it cannot be claimed later. Therefore, it is advisable to be pessimistic about the service life to be expected from all equipment. If the taxpayer grossly underestimates the durability of a machine, however, the Revenue Service will require a revision of the depreciation rate.

Usual methods of depreciation are briefly discussed in Chapter 5 in the section on Cost of Ownership. Your local Internal Revenue office will provide you with a copy of the most recent tax information on depreciation, which will help you to keep up to date on this subject.

One final word of warning is appropriate. Do not overlook the fact that the expected life of the mine itself may be a limiting factor in estimating the life of the equipment. One must not, for example, estimate the life of permanent buildings at the mine as 25 years if the deposit will be exhausted in 10 years. For best results, consult an accountant experienced in tax law as it applies to mining ventures.

SAFETY PROVISIONS

Costs of safety provisions in mining are really an operating expense, but if accidents can be prevented, these costs will turn into potential savings. Accidents are not only demoralizing and detrimental or destructive to human life but also costly. In Chapter 5, it was stated that the cost of Workers' Compensation insurance in Montana is more than 21% of the wages paid to underground miners. If the accident rate can be reduced, the insurance premium can probably also be reduced.

Until 1966, most non-coal-mine safety enforcement was strictly a state function. Most states have laws and agencies responsible for mine safety. In 1966, Congress passed Public Law 89-577 titled "An Act to Promote Health and Safety in Metal and Nonmetallic Mineral Industries, and for Other Purposes." Originally the administration of this act was under the U.S. Bureau of Mines, but on May 7, 1973, the Secretary of the Interior created a Mine Enforcement and Safety Administration (MESA) within the department and transferred the responsibilities of Public Law 89-577 to this new division. This new organization also assumed responsibility for the Federal Coal Mine Health and Safety Act of 1969.

The law requires that health and safety standards be developed, promulgated, and enforced to protect the workers. To accomplish this task, the act authorizes the Secretary or his duly authorized representative to withdraw workers from mines or sections of mines where imminent danger exists or where notices of violations have not been complied with in the allotted time.

These rules and regulations apply to almost all mines, so their import must be considered in all present and proposed operations. MESA is in the process of implementing the intent of the act, that is, the development, promulgation, and enforcement of safety standards. At the time of writing, these rules are being published in the Federal Register, and MESA does not have a compilation of all existing rules and regulations for general circulation, but they should be available soon.

When two government agencies (state and federal) impose rules and regulations, the question arises as to which one governs—or must the operator satisfy both agencies? The general rule is that if the state law is stricter than the federal law, the state law applies, and vice versa. The operator must comply with the stricter of the two sets of laws. In initial planning of a mining operation, these laws should be reviewed so that capital requirements can be determined. It is likely to be cheaper to incorporate these requirements at the start rather than to make changes at some later date after an inspection.

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CHAPTER 8 — MINE ACCOUNTING

By

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OBJECTIVES OF MINE ACCOUNTING

Mine accounting, as discussed in this chapter, includes accounting both for mining (ore extraction) and for mineral beneficiation. This chapter is not a manual on how to set up an accounting system; it is a discussion of the general concepts of accounting, for mining in the broad sense, that is, including both ore extraction and milling. The accounting objectives are the same in both. The purpose of this chapter is to show what can be expected from an accounting system in the way of information and how the information can be used for controlling operations.

Two kinds of accounting are needed in mining or milling. One, metallurgical accounting, involves keeping records of weights, moisture content, assay values, concentrates, and tailings. This kind of accounting is extremely important in order to know what and how much is produced, but it is discussed in another section of this handbook. The second type of accounting deals with cost and revenue record keeping, and it is this aspect of accounting that is discussed in this chapter.

Small mining companies seem to be characterized by deficiencies in the financial and cost-keeping type of accounting. It has been demonstrated time and time again that inadequate accounting, or inadequate use of accounting, is an important reason for the high mortality rate among mining ventures. Accounting provides signposts to tell you where you are going in a financial sense. Without signposts you may not know where you are until it is too late.

FINANCIAL VS. COST ACCOUNTING

Accountants classify accounting into two general divisions based on the system's primary objective. If an accounting system is designed to produce information for the primary purpose of preparing financial statements, i.e., the income statement and balance sheet, it is referred to as financial accounting. On the other hand, if an accounting system is designed to show detailed costs of each operation, it is known as cost accounting. The systems are interrelated; financial accounting is needed to produce financial statements, and cost accounting is needed to show costs of operations or product costs. It is possible to have financial accounting without cost accounting, but it is not possible to have a system of cost accounting without basic financial accounting.

Financial statements are the end product of any accounting system. They are essential to provide owners with an overall view of financial operations—the balance sheet shows the financial position of the company at a particular date, and the income statement shows the results of operations for the period.

Some businesses get along very well without a cost system because of the nature of their activity. Mine accounting, on the other hand, is incomplete if it does not provide detailed cost information. The nature of mine operations makes it imperative that reliable cost information be available and timely.

COST ACCOUNTING AS AN AID TO MANAGEMENT

Technically, mining refers to the extraction of ore from the earth, but in this chapter the term 'mining' will refer to both ore extraction and milling. The accounting concepts involved in ore extraction are similar to those for milling. All that is needed is an expansion of the accounting system to cover the special needs of each type of operation.

An accounting system should provide a mine or mill operator with:

1. Unit of production
2. Total cost for the period
3. Division of total cost into labor, supplies, overhead, and service costs.

The characteristics of a mining operation will determine the amount of cost detail required. For example, a mining company operating a single open-pit mine would need only a single account in which all mining costs are accumulated. Management would, however, be interested in the nature of the costs incurred. In order to provide such information, labor costs should be classified by functions so as to differentiate between wages paid shovel crews, drillers, truck drivers, etc. Likewise, supplies, power, and service department costs should be charged to specific functions.

The cost information required in a shaft-mine operation could be as simple as that for an open-pit mine; the mine could be treated, for cost purposes, as a single operation. In this type of operation, however, usually several levels and stopes are being worked at the same time. A cost system can be more useful to management if costs are accumulated according to locations or working places. In other words, instead of having one account in which all mining costs are accumulated, there would be several accounts—one for each working place. As working conditions in each location are likely to be different, it follows that the cost of getting out a ton of ore, or the cost of advancing an opening a foot, probably will show differences also. If costs in a particular location exceed the recovery value of the ore extracted, it would be more economical to close down that location, unless there is a good reason to expect an improvement in the value of the ore to be recovered, or unless costs can be reduced.

Management would not know that costs are excessive unless adequate records are maintained. Overall mine costs might appear satisfactory, owing to low-cost operations in other locations. If a high-cost operation could be eliminated, or if its costs could be reduced, greater profit would be realized from mine operations.

In a similar fashion cost accounting provides cost data for different operations in a mineral beneficiation plant. Although here it is not possible to shut down an operation (location) because of excessive costs, it might be possible to reduce costs if they are known to be excessive. Obviously, it is necessary to know what costs are, before management can be alerted to the problem.

It should be apparent that accounting, and particularly cost accounting, provides management with the means of controlling operations for greater profits. This is the primary function of mine cost accounting—assistance to management. By knowing what current costs are and by comparing them with past costs or with estimates as to what costs should be (a budget), management is in a much better position to eliminate some of the guess work usually inherent in any business operation.

COST FLOW

From the time a mining operation is started until the last ton of ore is extracted and processed, all costs incurred, at whatever stage of operation, flow along until they are all accumulated and, in a sense, are attached to each ton of concentrate produced. The final test of whether total operations are successful is the relation of the final cost to the selling price of the product.

To help visualize cost flow, and understand the function of accounting, a cost flow chart is presented below.

This chart is not intended to depict all costs; it is intended to portray the general idea of cost flow.

Production costs can be divided into direct and indirect costs. Direct costs are those that can be traced to a specific operation. For example, wages paid to a miner working a stope and wages paid to a machine operator in the mill are direct costs. In general, indirect costs are those that cannot be traced directly to the production of a unit of product (ton of ore). The greater the detail in which costs are broken down into operations, the greater will be the proportion of indirect costs to total costs. In a single open-pit mine, wages paid to shovel crews, drillers, and truck drivers, and the cost of services are all direct costs. On the other hand, if a mine is divided into several working places, for costing purposes, numerous costs that benefit the mine as a whole, rather than a particular location, are treated as indirect costs. These indirect costs, in turn, may be allocated to working places on some rational basis. Total production cost for each working place is then available.

A milling operation takes the cost flow from mining, expressed in total amount and on a per-ton basis. To this cost is added the cost of crushing, which in turn passes the total cost on to grinding, and so on until the last operation is completed.

Mining

Place 1	**Place 2**
Direct costs:	**Direct costs:**
Labor	Labor
Supplies	Supplies
Repairs	Repairs

Overhead and redistributables

Labor
Supplies
Power
Repairs
Depreciation
Supervision
Other

} Cost of ore produced {

Milling

Crushing	**Grinding**	**Flotation**	**Hauling**
Direct costs:	**Direct costs:**	**Direct costs:**	**Direct costs:**
Labor	Labor	Labor	Labor
Supplies	Supplies	Supplies	Supplies
Repairs	Repairs	Repairs	Repairs

Overhead and redistributables

Labor
Supplies
Power
Repairs
Depreciation
Supervision
Other

} Total cost of concentrates produced

COST FLOW CHART

From an accounting point of view, each different operation is a cost center. This means that costs are accumulated at that point for purposes of cost measurement and comparison with past costs, or ideally, with a predetermined estimate. Furthermore, each different operation is also a responsibility, performance is more easily measured, and management is in better position to appraise the efficiency of operations.

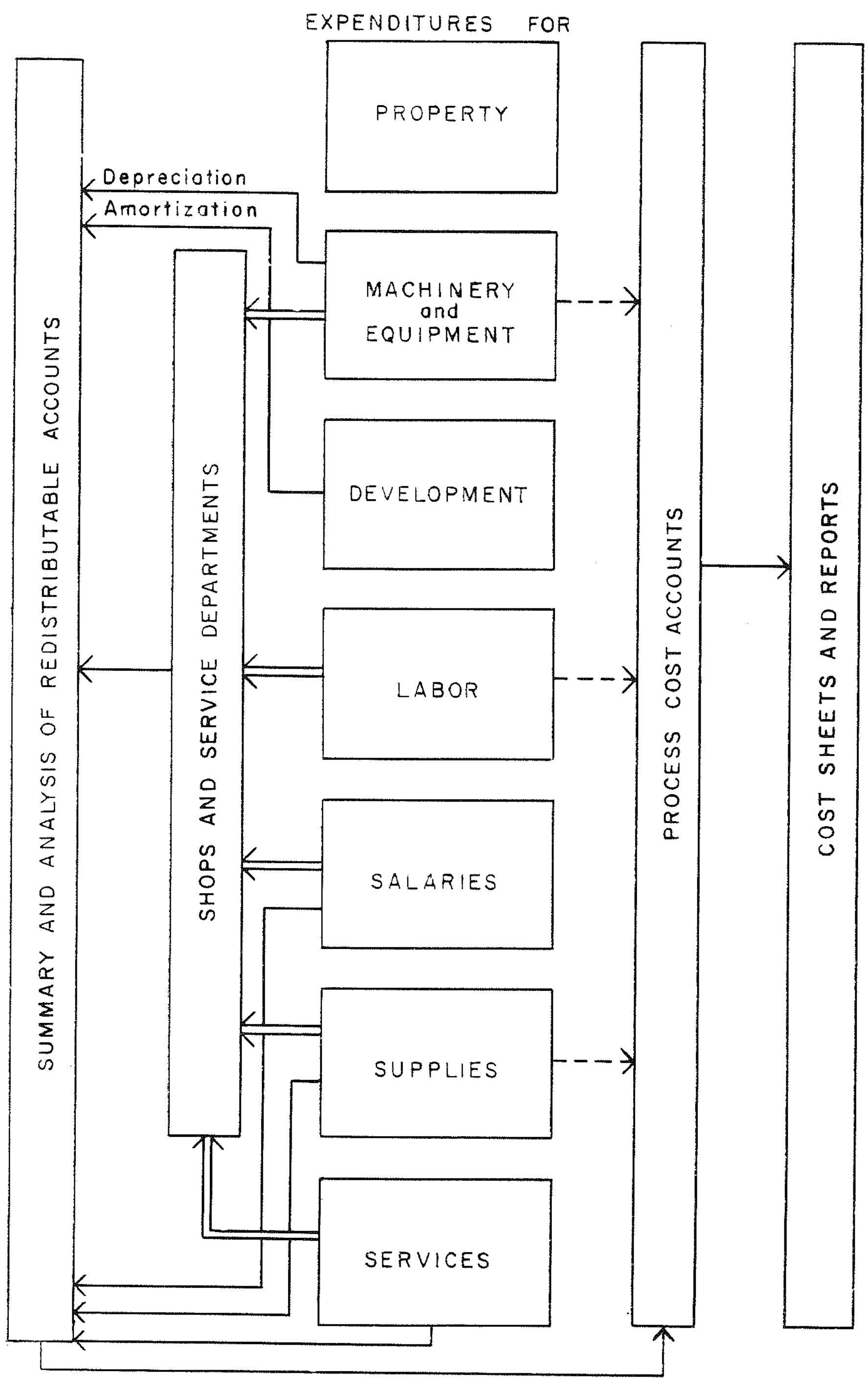

FIGURE 8-1.—Composition of process cost accounting and cost sheets. Adapted from Economics of the Mineral Industries, "Accounting for the Extractive Industries," Maurice E. Peloubet, AIME, 1959, by permission.

ACCOUNTING FOR LABOR, SUPPLIES, AND REDISTRIBUTABLES

Figure 8-1 shows the general plan of an accounting system applicable to both mining and milling. Note the route that the six general classes of costs take in order to be summarized in cost accounts. Some costs go directly to the cost accounts whereas others are first summarized and then redistributed to the cost accounts.

This section will discuss, in general terms, the three most important cost items: labor, supplies, and redistributable expenses.

ACCOUNTING FOR LABOR

Payroll accounting's first job is to accumulate the earnings of all employees whether they are hourly workers or on salary. The forms illustrated in Figure 8-2 and Figure 9-13 are suitable for this purpose, although almost any standard payroll form would be adequate. The important thing is to show (1) total amount earned, (2) deductions, (3) net pay, and (4) description of work performed.

Equally as important as determining total payroll is the distribution of total payroll to cost centers. Unless labor costs are properly allocated to working places and departments, there will be no way of checking on the efficiency of specific operations. Payroll distribution is best accomplished by summarizing all individual payroll cards on a payroll summary sheet (Fig. 9-15). Note that total earnings are charged (distributed) to the departments or cost centers in which the labor was performed.

According to Federal and Montana laws employers are required to withhold from employees' wages a prescribed amount for (1) Federal Income Tax, (2) Federal Old Age Benefit Tax, and (3) State Income Tax. Amounts withheld from employees must be carried in a liability account until paid, usually quarterly. Employers are also subject to certain payroll taxes, e.g., Federal OAB Tax, State Unemployment Compensation Tax and, under certain conditions, the Federal Unemployment Compensation Tax. In addition, employers must make payments, based on payroll, for Industrial Accident Insurance. All of these payments represent expenses of doing business. Note that withholding from employees do not constitute an expense of the business.

TIME CARD

Name________ Pay period________

Employment no.________ Social Security no.________

Hours regular time________ Rate________ Amount________

Hours overtime________ Rate________ Amount________

Total hours________ Payroll wage amount________

Payroll deductions: Federal income tax________ O.A.S. Ins.________

State income tax________ Total withholding $________

Employee deductions: Bonds________ Other________

Total earned________ Total withheld________ Bal. due________

TIME RECORD

Date		Hours worked	Shift	Description of Work	Remarks
	Monday				
	Tuesday				
	Wednesday				
	Thursday				
	Friday				
	Saturday				

FIGURE 8-2.—Employee's time card.

ARTICLE ____________

Date	RECEIVED						ISSUED			ON HAND		
	Order no.	Quantity	Invoice price	Freight	Total	Unit price	Req. no.	Quantity	Amount	Quantity	Unit price	Amount

FIGURE 8-3.—Example of stores card for supplies.

Dixon Fagerberg, C. P. A., in his article "Mining Enterprises"* wrote that, "Aside from the important job of assembling the facts, the real responsibility of payroll accounting is to give management an answer to this big question: Is fair value received for those labor dollars? Payroll accounting is thus properly charged with the never-ending job of improving the ratio of time units to physical units, such as number of feet advanced, number of cars of ore and waste hoisted and sticks of dynamite used. In correlating the hours or time units with units of actual accomplishment, one of the areas justifying special attention is where premium labor rates are paid not for what is being done but for when or where it is being done. Special detailed reports on overtime, showing the reasons why it was necessary, who authorized it, the department, and names of employees, should eliminate abuses in this area.

"In short, payroll accounting's task is far more than clerical. It is the liaison between management and the shift boss who actually supervises his men in their daily work. Payroll accounting is expected over a period of time to develop a seventh sense for detecting poor productivity, unhealthy morale, or general apathy."

ACCOUNTING FOR SUPPLIES

Supplies, like cash, should be subject to control against waste and loss. When supplies are readily available to workmen, they are likely to be consumed wastefully and may even disappear completely without any benefit being derived from them by the company. Weather, also, takes its toll of supplies left unprotected from the elements.

It should be obvious, then, that supplies, regardless of their nature, should be properly protected in a warehouse until issued for use.

As purchased, supplies should be charged to a stores account. Use can be controlled by means of stores requisitions. The storekeeper should issue supplies only upon receipt of a proper requisition, which describes the item(s) wanted, identifies the job on which they are to be used, and is signed by the shift boss or foreman. From his records the storekeeper can calculate the cost of the supplies issued. Completed stores requisitions serve as the basis for allocating supply costs to cost centers.

The best control over supplies is obtained by using a stores card for each class of supplies carried. Each class of supplies should be stored in its own individual compartment and a stores card prepared for the units on hand. As units are purchased they are added to the quantity indicated on the card, and as they are issued, as shown by a stores requisition, the quantity on the card is reduced. In other words, a perpetual inventory is maintained for each class of supplies. Figure 8-3 illustrates a stores card.

*Encyclopedia of Accounting Systems, v. 9, Prentice-Hall Inc., 1957, p. 1281-1316.

Stope or development costs

Working place ______________________ Description ______________________

Date started ______________________ Objective ______________________

Level ______________________ Month ______________________ 19___

	Day of month							Total	Average per unit
	1	2	3	4	5	6	etc.		
Labor: Miners Noncontract Others									
Total labor									
Supplies: Timber Powder Bits Steel Other									
Total supplies									
Total direct cost									
Redistributables: Maintenance Supervision Surface plant Other overhead									
Statistics:									
Tons produced									
Ft. of development driven									
Cost per unit									

FIGURE 8-4.—Stope and development cost.

REDISTRIBUTABLES

Several references have been made to direct costs. Other costs, no less necessary, apply to several operations and locations and consist of services such as electric power, water, and maintenance and repair shops, as well as administration, taxes, depreciation of equipment, and amounts of deferred exploration and development written off against ore produced. These costs are referred to as redistributables or indirect costs.

Redistributables, as the title suggests, are distributed to producing departments. When direct costs are properly charged to operations and when indirect expenses are properly distributed, the total cost for each major operation becomes obvious. It is not necessary to make distributions formally in the accounts; by making the distribution on work papers only, a great deal of unwieldiness and clogging of the books of account can be avoided.

The following bases have been used for distributing indirect expenses to production departments. These are merely illustrative; other bases may be used.

Cost to be distributed	Basis of distribution
Electric power	Horsepower of machines, number of electrical outlets
Warehouse expense	Number of requisitions
Blacksmith and machine shops	Direct labor costs in each producing department
Assaying	Number of assays
Administration	Number of employees in producing departments

REPORTS TO MANAGEMENT

From reports containing the data available from a good system of accounting, management can watch the progress of every phase of the business. In addition to telling the story in an understandable manner, reports must be timely in order to be of value, that is, they must be available soon after the end of the period covered. A report for September received the first of November has less value to management than if it had been received on the 10th of October. The purpose of reports is to inform management of operating conditions. If excessive cost or inefficiencies are observed, corrective action must be taken promptly.

Each mining operation has its own special characteristics; no two mines are alike. Consequently, reports to management must be tailored to meet individual requirements. Several types of reports are illustrated below. These reports show the kind of information some mining companies are obtaining from their accounting systems. They may not meet your special requirements, but they should suggest ways of presenting certain accounting data usefully. With minor changes, these reports could be made to fit almost any mining situation.

MINE STOPE OR DEVELOPMENT COST REPORT

Figure 8-4 illustrates a cost report for mine operations that will enable management to watch the cost of ore extraction or tunnel advance in each working place. For closest control this information should be available on a daily basis. The line 'Total Direct Cost' is the key to the report. Such costs are controllable by the shift boss or mine foreman, to a considerable extent, and from daily examination of these controllable costs the effectiveness of the foreman can be evaluated. Costs listed below Total Direct Cost are redistributables and are usually not available on a daily basis except as a predetermined rate (estimate) is used. The effectiveness of this report as a control device would not be greatly diminished if it were limited to direct costs only—the controllable costs.

MILLING COST REPORT

Figure 9-26 illustrates one type of milling cost report. In this report, general expenses are not distributed to specific operations. These expenses could be distributed, however, so that each operation would stand on its own full cost basis. The illustrated report form enables management to check on performance of each department because all departmental expenses are direct expenses and, hence, controllable to a considerable extent by the department foreman.

MONTHLY SUMMARY OF EXPENSES

Monthly costs and expenses may be brought together in a summary report for management on the order of the one illustrated in Figure 8-5. This form provides management with financial information concerning total operations. The report, like any other operating information supplied to management, should be compared with a standard of performance in order to provide a basis for appraisal. In lieu of a standard, the report for the previous month or prior months is often used for comparison, but this procedure is not effective if past operations were characterized by low production and by operating inefficiencies.

STATEMENT OF INCOME

To show whether a mining venture has been profitable or not, a statement of income must be

Monthly summary of expenses, (month), 19.........

	Mine expense				Loading and shipping expense								
	Development	Mining	Other	Total	Crushing	Milling	Ore	Concentrates	Misc. surface expense	General expense	TOTAL EXPENSE	Additions to plant and equipment	TOTAL EXPENDITURES
Labor:													
Direct													
Service													
Supervision													
Compensation													
Supplies:													
Timber													
Explosives													
Flotation													
Other													
Sundries:													
Power													
Contract drilling													
Contract trucking													
Rents paid													
Tel. & tel.													
Property taxes													
Fire insurance													
General office													
*Misc.													
Operating exp.													
Gen. exp. distri.													
Total													
Cost/ton													

	Milling ore, wet tons	Shipping ore, wet tons	Total ore mined, wet tons	Crushing, dry tons	Milling, dry tons	Lead ore, wet tons	Lead concentrates, wet tons	Zinc concentrates, wet tons
Statistics:								
Tonnage								
Cost/ton								
Operating days								
Tons/day								

*Includes compressed air plant, water system, assaying, autos, trucks, misc. gen. surface.

FIGURE 8-5.—Monthly summary of expenses.

prepared. Such a statement may be prepared monthly or quarterly, but certainly not less frequently than once a year. Statements of income at more frequent intervals keep management better informed about progress than statements prepared only once a year. Figure 8-6 presents a statement of income for a typical mining company.

Noname Mining Company
Statement of income
for the year ending December 31, 19——

Sales value of metallic content of ores		———
Less charges for smelting, refining, and freight		———
Net proceeds for sale of ore		———
Other income from property		———
Gross income from mining		———
Cost of sales:		
Operating expenses	———	
Maintenance	———	
Repairs	———	
Development	———	
General and administrative expenses	———	
Depreciation	———	
Depletion (based on cost)	———	———
Net income before taxes		———
Federal income taxes		———
Net income		———

FIGURE 8-6.—Statement of income.

CHAPTER 9 — MINERALS BENEFICIATION ACCOUNTING

By

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Revised and edited by
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INTRODUCTION

Too often, small concentration or extraction enterprises treating 25 to 300 tons of ore daily neglect to keep proper metallurgical and cost accounting records from the inception of operations. Such indifference may be a deciding factor in the success or failure of the enterprise, particularly if it be at all marginal.

For the smaller milling plants, the records are simple and easily kept; most larger mills require more details of metallurgy and costs. It is the purpose of this section to indicate the elements and procedures from which metallurgical and cost reports are derived, together with typical record forms.

Additionally, factors affecting a decision as to whether or not a concentration plant should be built are considered and examples given.

Minerals Beneficiation Accounting is considered in three parts: Metallurgical Accounting, Cost Accounting, and Economics.

METALLURGICAL ACCOUNTING

Of primary concern in metallurgical accounting are the weights, moisture content, and assays of the ore treated and the concentrates and tailings produced. The intermediate products, such as middlings, cleaner tailings, and the like, are assayed, for operating control but are not considered in the accounting procedure, because they are really constants in circuit.

Thus, the following items are essential to the preparation of a metallurgical accounting report:

- Weights—ore received and treated, and products
- Sampling—of above for moisture and assay; and ore feed rate
- Assaying
- Calculation of dry weights and metal or mineral contents
- Inventory—taken the first of each month—of ore and concentrates (or bullion and gold solutions) on hand
- Metallurgical balance sheets
- Unaccountables

WEIGHTS

Unless the milling plant or concentrator is served by a railroad (in which case railroad weights may be used), a truck or mine car scale should be a planned part of mill equipment. Preferably, the scale should be one that prints weights on a ticket. Each ticket should bear a Lot Number and show the gross, tare, and net weights, and the date. (See Fig. 9-1 and Fig. 9-4 for recorded forms.) Accurate weights, both of ore received and products made, are most important; they form the base of any metallurgical accounting report. A weighing conveyor, such as a Merrick Weightometer, is a great convenience, but may be too expensive for small plants. Initially, and at regular intervals thereafter, the scales should be serviced by the State Inspector of Weights and Measures.

SAMPLING

Mill feed and products.—Ore treated and all final products, such as tailings and concentrates, should be sampled at regular intervals. The use of automatic samplers for these products cannot be too strongly urged; maximum interval between cuts should not be more than 15 minutes.

Specifically, automatic samplers should be placed at these points:

a. Between secondary crusher and fine-ore bin, where the ore is sufficiently fine to cut. This sample (with certain precautions) may be used for moisture, as well as for assay of the ore.

b. To cut the classifier overflow. This gives a second ore sample, which because of the fineness of the ground product is more accurate than that taken under (a). It is a check on (a) and is generally employed in the metallurgical report.

c. Final tailings as they leave the mill.

d. Final concentrates, before entering bin or thickener.

To further indicate the location of automatic samplers, and their subsequent use for clarifying metallurgical calculations, a flow sheet of a lead flotation mill is outlined in Figure 9-2.

*Deceased.

Form No. 1

DOMESTIC MANGANESE AND DEVELOPMENT COMPANY, AGENT
Metals Reserve Company
Butte, Montana

Compiled by________Date_____
Checked by________Date_____

Description ORE RECEIVED

DATE 1950	CAR Initial	CAR Number	MILL Lot No.	SAMPLE No.	% H_2O	WET WEIGHT-POUNDS Gross	WET WEIGHT-POUNDS Tare	WET WEIGHT-POUNDS Net	H_2O Pounds	DRY WEIGHT Pounds	DRY WEIGHT Tons
10-1		86	200	918	3.2	40,200	10,100	30,100	963	29,137	14.5685
		42	"								
		31	"								
		27	"								
		48	"								
		52	"								
		86	"								
10-31			230	1302	4.1						
			"								
			"								
			"								
			"								
			"								
			"								
		72	"			42,000	10,000	32,000	1312	30,688	15.3440
Total	for Month				3.76	11,062,550	2,750,000	8,312,550	312,550	8,000,000	4,000.0000

FIGURE 9-1.—Form for recording weights of ore received at mill.

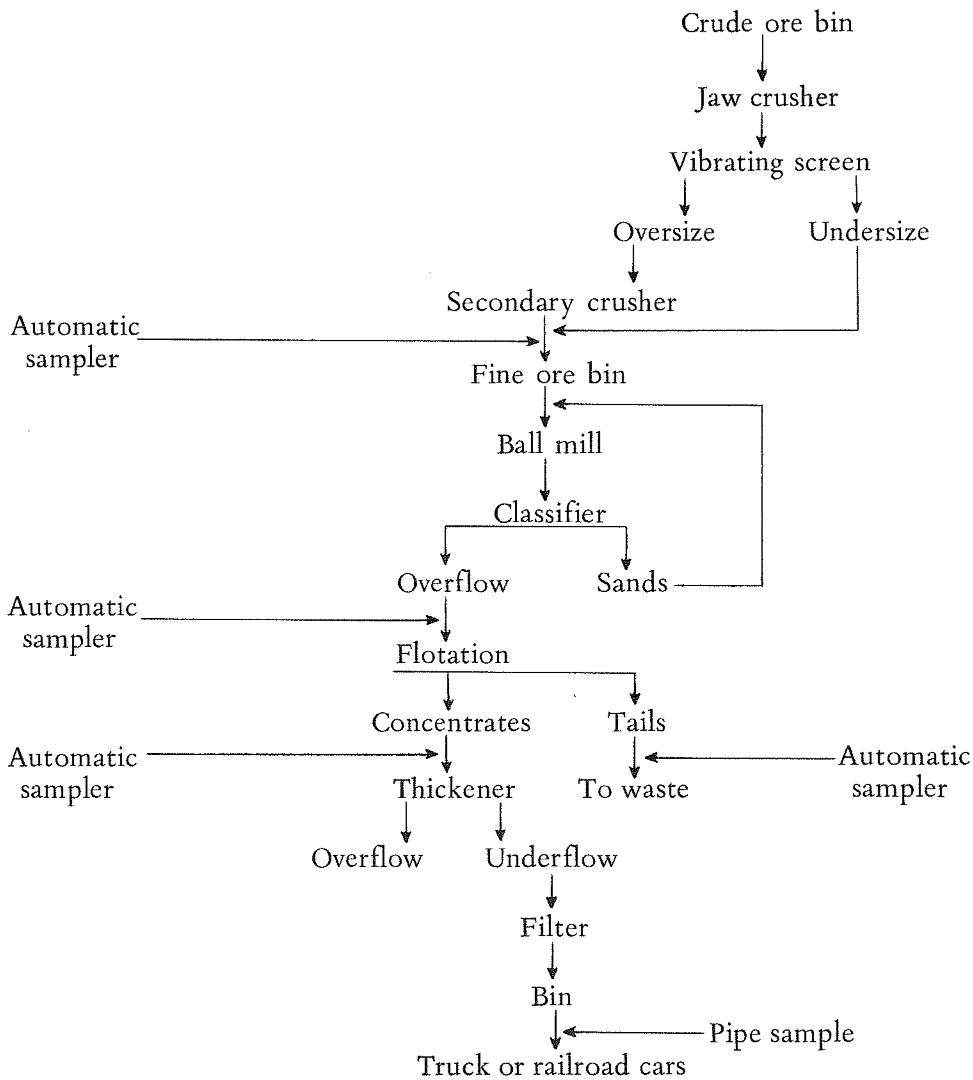


FIGURE 9-2.—Flow sheet of lead flotation mill.

Mill feed tonnage.—The tonnage of ore received does not necessarily coincide with ore treated during any given period. Therefore, for proper mill operation, it is necessary to determine the feed tonnage rate at uniform intervals. This may be done in several ways:

a. By means of a gate and chute, divert the feed for ball mill or rolls into a box resting on a scale for a definite time interval, say 10 or 15 seconds (sec.) and weigh.
b. By stopping the belt feeding the ball mill or rolls (the speed of which is known in feet per minute), removing a 5- or 10-foot section of the ore on the belt, and weighing it.
c. These samples are usually taken every hour and are conveniently calculated in tons per hour (tph).

Examples:

a. Gate and chute—10-sec. samples
Net wet weight = 35 lb.
$$\text{Lb./hr.} = 35 \times \frac{60}{10} \times 60 = 12{,}600$$
$$\text{TPH} = \frac{12{,}600}{2{,}000} = 6.3 \text{ (wet)}$$

b. Sample from 5-ft. section of feed belt to ball mill or rolls
Belt speed = 50 ft./min. (fpm)
Net wet weight = 20 lb.
$$\text{Lb./hr.} = 20 \times \frac{50}{5} \times 60 = 12{,}000$$
$$\text{TPH} = \frac{12{,}000}{2{,}000} = 6.0 \text{ (wet)}$$

Hourly sample tonnages are added for either shift tonnages or 24-hour tonnages, corrected for actual running time. These samples may be used for determining moisture, but they are not as accurate as those described in (a) under **Mill feed and products.** The total sample tonnage should be checked monthly with actual weights of ore received, corrected for moisture, with allowance for inventory gain or loss; then a factor can be derived for use with the sample tonnage to make it coincide closely with actual weight of ore treated.

For example, the summation of hourly tonnage samples, corrected for running time, is 4,100 wet tons. The actual quantity of ore treated is 3,750 dry tons for the same period. Dividing 3,750 by 4,100, the factor 0.833 is obtained. Therefore, this factor is applied directly to the hourly tonnage samples and may be used for a month, or until a new factor is calculated.

For convenience, either a tabulation or a graph may be made showing hourly tonnage rates corresponding to hourly sample weights in which the weight of tonnage box is included (provided the same box is employed at all times), thus avoiding the necessity of subtracting the weight of the box.

Assuming that the ore burden from a 5-foot section of the feed belt to the ball mill is taken (as an example b), a tabulation (Fig. 9-3) shows the derivation of a feed rate in dry tons per hour. Note that the factor 0.833 covers both sampling errors and moisture content. For use in the milling plant, the tabulation is limited to two columns; weight of sample plus box, in pounds, and dry tons per hour.

Concentrate shipments.—Shipments by truck or railroad car are 'pipe sampled' in a regular pattern, for moisture, and assay as a check on smelter returns, and of course, they are weighed.

Composite samples.—In many plants, composite samples of mill feed, concentrates, and tailings are made monthly as checks on the calculated assays from daily production. From each daily sample, a weight proportionate to the tonnage milled or produced on that day is taken and, at the end of the month, each sample is complete. Each is thoroughly mixed and analyzed for many elements not required in daily reports.

Another method of obtaining weights for daily samples making up composites is to employ the dry weights of the automatic samples.

Sample dryers. — Dryers may be heated by steam, electricity, gas, solid fuels, or heat lamps. Temperatures should be held much below any possible decomposition point of ore minerals, generally 100° to 125°C.

Identifying samples.—One or two methods of identifying samples are in general use:

a. If daily number of samples does not exceed 20, the samples are identified by date, shift number, and product, as: October 20, 1959, Shift 1, Mill feed.
b. Otherwise, the samples may be numbered consecutively, but only the date and sample number appear on the pulp envelope sent to the assay office. The sample room makes out a sheet correlating the date, shift number, and product, which together with the assay report is sent to the mill office.

ORE FEED TONNAGE SAMPLES

Feed belt to **Ball Mill**—5-foot section

Pounds					
Sample and box	Box	Net	Ton/hr.	X factor	Dry tons/hr.
25	15	10	3.0	0.833	2.50
26	15	11	3.3	0.833	2.75
27	15	12	3.6	0.833	3.00
28	15	13	3.9	0.833	3.25
29	15	14	4.2	0.833	3.50
30	15	15	4.5	0.833	3.75
31	15	16	4.8	0.833	4.00
32	15	17	5.1	0.833	4.25
33	15	18	5.4	0.833	4.50
34	15	19	5.7	0.833	4.75
35	15	20	6.0	0.833	5.00
36	15	21	6.3	0.833	5.25
37	15	22	6.6	0.833	5.50
38	15	23	6.9	0.833	5.75
39	15	24	7.2	0.833	6.00
40	15	25	7.5	0.833	6.25
41	15	26	7.8	0.833	6.50
42	15	27	8.1	0.833	6.75
43	15	28	8.4	0.833	7.00
44	15	29	8.7	0.833	7.25
45	15	30	9.0	0.833	7.50

FIGURE 9-3.—Form for determining ore feed tonnage in dry weight.

ASSAYING

Assays should be made at the milling plant, if at all possible, because the shortest time interval between the taking of samples and receipt of assay results ensures best metallurgical operation.

The smelter or other plant to which concentrates are shipped will submit a list of umpire assayers from which several may be chosen. These umpires may then be used in rotation in case of a difference between the mill assay and the smelter's assay on the same shipment. Other umpire assayers may be suggested for the smelter's approval. The services of umpire assayers are valuable to the shippers, because, on the average, their costs will be more than repaid by increased receipts.

CALCULATION OF DRY WEIGHTS

Pursuant to the preparation of metallurgical balance sheets, ores treated and concentrates produced must be reduced to a common or dry base. For this purpose, Form 1 (Fig. 9-1) is employed. The figures on it refer to **ore received.** First, the data from the scale weight tickets are entered on this sheet: the date, the car or truck number, and the gross, tare, and net weights. About 7 to 12 truckloads of ore may form one lot number, and the sample taken by an automatic cutter will represent all of these loads. At the sample room, the lot number and sample number are given and, together with the moisture percentages, are entered upon the sample sheet. Later, these figures are posted on Form 1 (Fig. 9-1). At the end of the month, all columns are totaled and checked. The average percentage of moisture is calculated, and the dry weight represents ore received during the month.

Similarly, on the same form, concentrate shipments weights and moisture percentages are recorded. The totals represent concentrates shipped during the month.

Additionally, weights and moisture contents reported on the smelter returns may be entered on Form 1. The totals are used as a check upon the smelter figures and in the preparation of a metallurgical balance sheet, **settlement weights and assays.**

MINERAL AND METAL CONTENT CALCULATIONS

As an example, data concerning 'Mill feed—classifier overflow' are used. It is assumed that the automatic cuts for the shift samples have been combined as a composite according to hourly tonnage figures representing a 24-hour or daily run. This sample is generally used for mill feed tabulations after the hourly tonnages are corrected by a factor as shown before.

First, from the daily mill reports the hourly tonnages are totaled for the day. The result in dry pounds and dry tons is entered on Form 2 (Fig. 9-4). When received, assays also are entered on Form 2.

Form No. 2

DOMESTIC MANGANESE AND DEVELOPMENT COMPANY, AGENT
Metals Reserve Company
Butte, Montana

Compiled by_____ Date_____
Checked by_____ Date_____

Description MILL FEED -- CLASSIFIER OVERFLOW

DATE	Sample	WEIGHT		ASSAY							MINERAL CONTENT						
1959	No.	Tons	Pounds	Mn %	Ag oz	Au oz	Fe %	Zn %	Pb %	Insol %	Mn Pounds	Ag Ounces	Au Ounces	Fe Pounds	Zn Pounds	Pb Pounds	Insol Pounds
10-1	919	149	298,000		16.0				7.0			2384.0				20,860	
10-31	1303	142	284,000		12.6				6.2			1789.2				17,608	
TOTAL		3900	7,800,000		14.2				6.5			55380.0				507,000	

FIGURE 9-4.—Form for recording daily mill feed tonnage at classifier overflow.

For simplicity, two assays, silver and lead, are shown. The silver is represented in oz./ton, which figure (16.0) must be multiplied by the dry tons (149) to obtain the number of ounces of silver contained in the feed. Similarly, the dry pounds (298,000) must be multiplied by the percentage of lead (7.0) in the feed to determine the number of pounds of lead contained.

Similar figures for each day are entered and calculated during the month. The totals of the columns indicate the apparent dry weights of ore figured during the month, together with the ounces of silver and pounds of lead therein, from which are calculated the average assays. These figures are then corrected by use of ore-received weights and ore inventory for final recording on the metallurgical report.

Under the heading **Composite samples,** it was mentioned that dry weights of daily automatic samples may be used for making up composite samples. These weights may also be employed in the calculation of monthly averages for product assays. This procedure is illustrated in Figure 9-5, using Form 2 for final mill tailings. Dry weights of the 24-hour automatic samples are entered under pounds, assays of silver and lead are entered in their respective columns. Multiplying the assays by the pounds gave figures of silver and lead that are neither ounces nor pounds but are relative factors. The columns of sample weights in pounds and the figures for silver and lead are totaled; the summation figures for silver and lead are divided by the total pounds to obtain the average ounces of silver and percent of lead in the final tailings for the month. These average assay figures are used in the metallurgical report for the month.

The same method is applied to concentrates or any other product that is sampled automatically. If concentrate weights and final tailing weights are obtained by time sampling or otherwise, these weights may be used, and, of course, a mineral content of silver and lead would then be expressed in ounces or pounds instead of a unit.

Concentrate shipments are recorded in the same manner; it is assumed that concentrates are transported by truck to railroad cars. When loaded they are 'pipe sampled' for moisture and assayed, and the car is weighed. Tare weights of the cars, as printed on their sides, are used. Weights and moisture figures are entered on Form 1 (Fig. 9-6), and totals for all shipments for the month are calculated. Dry weights and assays are recorded on Form 2 (Fig. 9-7), and weights, ounces of silver, and pounds of lead are totaled. From these figures, the average silver and lead assays are found.

It must be remembered that the total tons of concentrates shipped during the month may not represent the concentrates produced during that month. Some concentrates may have remained in the bins, both at the first and last of the month.

Form No. 2

DOMESTIC MANGANESE AND DEVELOPMENT COMPANY, AGENT
Metals Reserve Company
Butte, Montana

Description FINAL MILL TAILINGS

Compiled by ______ Date ______
Checked by ______ Date ______

DATE	SAMPLE NO.	WEIGHT		ASSAY							MINERAL CONTENT						
		Dry Weight	Dry Weight	Mn	Ag	Au	Fe	Zn	Pb	Insol.	Mn	Ag	Au	Fe	Zn	Pb	Insol.
1959		Tons	Pounds	%	oz	oz	%	%	%	%							
10-1	923		5.67		1.0				0.80			5.67				4.54	
10-2	930		6.00		0.9				0.75			5.40				4.50	
10-31			5.50		0.8				0.90			4.40				4.95	
Total for month			176.70		0.85				0.81			150.20				143.13	

FIGURE 9-5.—Showing use of Form 2 in calculating average monthly assay.

Form No. 1

DOMESTIC MANGANESE AND DEVELOPMENT COMPANY, AGENT
Metals Reserve Company
Butte, Montana

Description CONCENTRATE SHIPMENTS

Oct. 1959 - Mill Figures

Compiled by______ Date______
Checked by______ Date______

Date 1959	CAR		MILL	SAMPLE	%	WET WEIGHT-POUNDS			H_2O	DRY WEIGHT	
	Initial	Number	Lot No.	No.	H_2O	Gross	Tare	Net	Pounds	Pounds	Tons
10-8	NP	13411	202	940	10.6	122,000	40,000	82,000	8692	73,308	36.6540
10-31	NP	14652	212	1062	11.4	120,000	40,000	79,200	9029	70,171	35.0855
TOTAL FOR MONTH					11.0	1,168,080	404,040	764,040	84040	680,000	340.0000

FIGURE 9-6.—Use of Form I in recording weights of concentrate shipments.

Form No. 2

DOMESTIC MANGANESE AND DEVELOPMENT COMPANY, AGENT
Metals Reserve Company
Butte, Montana

Description CONCENTRATE SHIPMENTS

Oct. 1959 - Mill Figures

Compiled by______ Date______
Checked by______ Date______

DATE	SAMPLE NO.	WEIGHT		ASSAY							MINERAL CONTENT						
		Tons Dry Weight	Pounds Dry Weight	Mn %	Ag oz	Au oz	Fe %	Zn %	Pb %	Insol %	Mn Pounds	Ag Ounces	Au Ounces	Fe Pounds	Zn Pounds	Pb Pounds	Insol. Pounds
10-8	940	36.6540	73308		148.0				65.0			5424.8				47650	
10-31	1062	35.0855	70171		151.0				63.5			5297.9				44559	
Total		340.0000	680,000		150.8				64.7			51272.0				439960	

FIGURE 9-7.—Use of Form 2 in recording assays of concentrate shipments.

INVENTORIES

During the initial period of operating a milling or minerals beneficiation plant, a considerable part of the ore feed is consumed in the 'bedding' of ore bins, classifiers, thickeners, and other machines. Obviously, there will be no production from this portion of the ore feed, and for the first month at least, recoveries may be low. This part of the ore and products may not be regained until cessation of the mill operation; consequently, these bedding fractions are regarded as constant in quantity, and they do not enter into further calculation.

At the end of each month there may be considerable ore in the bins (in addition to the bedding). The quantity is estimated as closely as possible and recorded as ore on hand.

Ore Inventory—October 1959

	Wet tons	%H_2O	Dry tons
*On hand Oct. 1, 1959	90.00	3.50	86.85
**Ore received	4,156.28	3.76	4,000.00
	4,246.28	3.75	4,086.85
***Less ore on hand Nov. 1, 1959	75.00	4.10	71.93
Ore treated Oct., 1959	4,171.28	3.75	4,014.92

*Moisture (%H_2O) is that of ore received Sept. 30, 1959.
**From Figure 9-1.
***Moisture (%H_2O) is that of ore received Oct. 31, 1959.

The ore inventory shows that the tonnage of ore treated is greater than the tonnage of ore received, because there was less ore in the bins at the end of the month than at the beginning of the month.

Of equal importance are concentrate inventories. Depending upon the frequency of shipment, concentrates on hand at the end of any monthly period may be a considerable part of the production. If minerals are recovered by flotation, the concentrates flow to a thickener, thence to a filter and concentrate bins (see Flow Sheet, Fig. 9-2). The quantity of concentrates retained in the thickeners at the end of the month is almost constant and is so regarded unless abnormal conditions prevail. The filtered concentrate is conveyed to bins, which may be compartmented, each compartment holding a truckload. This arrangement makes it easy to estimate concentrates on hand.

METALLURGICAL BALANCE SHEETS

The basic factors required for the preparation of a Metallurgical Balance Sheet, such as weights, sampling, assaying, calculations, and inventory have been discussed. Most of the calculations shown have been concerned with a typical lead flotation mill, a flow sheet of which is given in Figure 9-2. The following metallurgical balance sheet reflects the operations of the same plant.

First to be entered on the Metallurgical Balance Sheet is the dry weight of the ore treated during the month. This is taken from the tabulation headed Ore inventory, above, and equals 4,014.92 dry tons or 8,029,840 dry pounds. These figures are entered on the first line (Mill feed), Figure 9-8. Mill feed assays are the monthly averages of silver and lead (Fig. 9-4). These are recorded on the first line (Mill feed), Figure 9-8. Multiply the dry tons of mill feed by the silver assay (oz./ton), and the dry pounds by the percentage of lead; the concentrates contain 50,559 ounces of silver and 433,839 pounds of lead.

The tonnage of the second major product, the mill tailings, is obtained by subtracting the weight of concentrates from that of the mill feed, resulting in a figure of 3,679.65 dry tons or 7,359,300 dry pounds. Corresponding assays of silver and lead are found in Figure 9-5 under final mill tailings which, together with the weights, are entered on line 3, Figure 9-8, under tailings. The tailings contain 3,128 ounces of silver and 59,610 pounds of lead.

If the weighing, sampling, assaying, and inventory estimates have been perfectly executed, the sum of the weights and metal contents of concentrates and tailings should equal the weight and metal contents of the ore milled. In this example, however, the silver contained in concentrates and tailings is 53,687 ounces, but the mill feed contains 57,012 ounces; there is a discrepancy of 3,325 ounces, which must be entered on the fourth line of the metallurgical report and marked Unaccountable. Similarly, the concentrates and tailings together contain 493,449 pounds of lead, but the mill feed has 521,940 pounds of lead, and the difference is 28,491 pounds of lead, which must be recorded on the Unaccountable line.

Remaining calculations of the Metallurgical Balance Sheet in Figure 9-8 are concerned with

Concentrate inventory—October 1959

	Wet tons	%H_2O	Dry tons
*Concentrates shipped	382.02	11.0	340.00
Less concentrates on hand, October 1, 1959	30.00	10.4	26.88
	352.02	11.0	313.12
Plus concentrates on hand, November 1, 1959	25.00	11.4	22.15
Concentrates produced	377.02	11.1	335.27

*From Fig. 9-6.

METALLURGICAL BALANCE SHEET

October, 1959

Product	Dry weight			Assay		Content		%Distribution	
	Tons	Pounds	%Total	Oz. Ag	%Pb	Oz. Silver	Lb. Lead	Silver	Lead
Mill feed	4014.92	8,029,840	100.00	14.20	6.50	57,012	521,940	100.0	100.0
Concentrates	335.27	670,540	8.35	150.80	64.70	50,559	433,839	88.7	83.1
Tailings	3679.65	7,359,300	91.65	0.85	0.81	3,128	59,610	5.5	11.4
Unaccountable						3,325	28,491	5.8	5.5

METALLURGICAL REPORT—USING CONCENTRATES AND TAILINGS

Product	Tons	Pounds	%Total	Oz. Ag	%Pb	Oz. Silver	Lb. Lead	Silver	Lead
Concentrates	335.27	670,540	8.35	150.80	64.70	50,559	433,839	94.2	87.9
Tailings	3679.65	7,359,300	91.65	0.85	0.81	3,128	59,610	5.8	12.1
*Mill feed	4014.92	8,029,840	100.00	13.37	6.14	53,687	493,449	100.0	100.0

*Calculated

FIGURE 9-8.—Types of metallurgical reports.

determinations of weight percentages of the products and distribution percentages of silver and lead. The mill feed must be 100 percent of the total; concentrate weights and tailing weights divided by the mill feed weight will give the weight percentages of concentrates and tailings, respectively. Likewise, the ounces of silver and pounds of lead in each product are divided by the ounces of silver and pounds of lead of the mill feed; distribution percentages of the products are taken. Thus, we find that the concentrate weight is 8.35 percent of the mill feed weight; the concentrates also contain 88.7 percent of the total silver and 83.1 percent of the total lead in the mill feed. The tailings contain 5.5 percent of the total silver and 11.4 percent of the total lead.

UNACCOUNTABLES

Theoretically, the sums of the metal contents of the tailings plus concentrates should equal metal contents in the mill feed. Figure 9-8 shows, however, that the silver content of concentrates plus tailings is 53,687 ounces, which is 3,325 ounces less than the 57,012 ounces in the mill feed. In a similar calculation, the lead in concentrates plus tailings is 493,449 pounds, or 28,491 pounds less than mill feed content of 521,940 pounds. These figures are entered on the line marked Unaccountable.

The unaccountable distribution percentages of silver and lead, 5.8 percent and 5.5 percent respectively, are much too great. A search must be made for sources of loss.

It was found that considerable quantities of froth collected on the pulp surface of the concentrate thickener, passed into the overflow, and joined the tailings **below** the automatic sampler. Further, although the floor washings were carried to a sump, they were pumped outside because of grease contamination. Remedial measures were taken at once; proper sprays were installed over the thickener to break down the froth accumulation, and the thickener overflow was piped to the tailing stream **above** the automatic sampler. Proper grease pans and other receptables were installed, and all floor washings returned to the rougher flotation circuit. As a result of these corrective actions, the unaccountable silver and lead percentages were reduced to less than 1 percent.

It must be understood that unaccountables represent the accumulation of all errors in weighing, sampling, and assaying, together with any losses incurred in mill operations. It is most important that the unaccountable factor be kept at a minimum.

In some plants, it is the habit of the operators preparing a metallurgical balance sheet to use concentrate weights and assays together with tailings assays (the tailings weight equals mill feed weight less concentrate weight) in calculating their mineral contents. Then, the sums of weights and mineral contents equal 100 percent, and the calculated mill feed assays are, of course, the metal contents of concentrates plus tailings divided by the ore feed weight. The difference in assays between the calculated mill feed and actual mill feed samples are either not shown or dismissed with a statement that mill feed assays are always greater than calculated assays and are, therefore, misleading. This is a very bad practice, not only because all errors of any kind are covered up or hidden, but eventually the accumulated losses may undermine the operation. The Unaccountable line should be a part of every metallurgical balance sheet, because it not only aids in locating losses but also requires constant vigilance to hold it at a minimum.

An example of the use of the concentrates plus tailings method is shown in Figure 9-8 below the Metallurgical Balance Sheet to which it directly refers. In this metallurgical report, unaccountables are completely ignored; metal contents of the concentrates plus tailings are assumed to be equivalent to the respective metal contents of the mill feed. Thus, the calculated mill feed assays 13.37 oz. of silver and 6.14 percent lead as against 14.20 oz. of silver and 6.50 percent lead of the actual mill feed shown above. The losses (unaccountable) of 3,325 oz. of silver and 28,491 lb. of lead are not mentioned. Further, metal recoveries in the concentrates seem to have risen to 94.2 percent of the silver and 87.9 percent of the lead as against the true figures of 88.7 percent of the silver and 83.1 percent of the lead.

MISCELLANEOUS METALLURGICAL REPORTS OR BALANCE SHEETS

Basin-Montana Tunnel Company.—For discussion, several metallurgical reports or balance sheets will be presented. The first is a Final Metallurgical Report of Basin-Montana Tunnel Company (Fig. 9-9). The operation comprises the fine grinding of a silver-lead-zinc ore and its flotation separation into four products—lead, zinc, and iron concentrates, and tailings. A review of the report indicates that the various metal contents of the four products were added together to determine the metal contents of the calculated mill feed. These metal contents are assumed to be 100 percent of the total. Comparing the calculated mill head with the actual mill head, the former has less gold (0.102 ounces vs. 0.105 ounces), but more silver, zinc, and lead, which is most unusual. Instead of the Unaccountable line, we have "percent accounted for", the figures of which present an interesting and odd situation. Altogether, 97.59 percent of the total gold in the mill head is contained in the four products, leaving an unaccountable loss of 2.41 percent. The total ounces of silver, pounds of zinc, and pounds of lead contained in the four products, however, are appreciably more than those shown in the actual mill head. Thus, we have an unaccountable gain of 8.31 percent for

BASIN-MONTANA TUNNEL COMPANY

Final metallurgical report - March 1941

Product	Dry tons	% Total weight	Assay				Metal content				% Recovery			
			Oz. Au	Oz. Ag	% Zn	% Pb	Oz. Au	Oz. Ag	Lb. Zn	Lb. Pb	Au	Ag	Zn	Pb
Mill head	1,936.8000	100.00	0.105	9.00	2.40	3.20	203.364	17,431.20	92,966	123,955				
Lead conc.	120.4025	6.22	0.505	100.46	3.17	52.24	60.812	12,095.38	7,635	125,787	30.64	64.07	7.06	85.78
Zinc conc.	47.9000	2.47	0.120	28.91	47.75	2.54	5.737	1,384.68	45,749	2,434	2.89	7.33	42.28	1.66
Iron conc.	343.5910	17.74	0.322	11.98	7.16	2.27	110.545	4,116.80	49,122	15,571	55.70	21.81	45.39	10.62
Tailings	1,424.9065	73.57	0.015	0.90	0.20	0.10	21.374	1,282.42	5,700	2,850	10.77	6.79	5.27	1.94
Total	1,936.8000	100.00					198.468	18,879.28	108,206	146,642	100.00	100.00	100.00	100.00
Percent accounted for							97.59	108.31	116.39	118.30				
Calculated mill head			0.102	9.75	2.79	3.79								

FIGURE 9-9.—Illustration of monthly metallurgical report, Basin-Montana Tunnel Co.

POLARIS-TAKU MINING CO., LTD.

Daily mill report

Date: September 30, 1938

METALLURGICAL DATA	Day	To date
Ore crushed—		
wet tons	105.0	5,720.4
% H_2O	2.3	2.7
dry tons	102.6	5,566.5
assay—oz. Au	0.335	0.298
contents oz. Au	34.371	1,661.239
Ore milled—		
estimated dry tons	194.6	5,683.8
actual dry tons		
Class. o'flow—		
assay—oz. Au	0.325	0.298
content—oz. Au	63.245	1,699.377
% Solids	31	1,699.377
pH		
Concentrates produced—		
wet tons		
% H_2O		
dry tons	15.02	363.53
Assay—		
oz. Au	3.79	4.17
% As		
Sb		
Content—		
oz. Au	56.926	1,515.620
Tailings (by difference)—		
dry tons	179.58	5,320.07
Assay—		
oz. Au	0.035	0.035
Content—		
oz. Au	6.319	183.757
Apparent recovery—%	90.0	89.0
Ratio of concentration	13.0	15.5

OPERATING DATA	Day	To date
Crushing plant—		
hours run	4½	156½
Mill—		
hours run	24	700
% running time	100	97.3
Balls added—		
pounds	350	10,500
Reagents—		
lb/ton feed		
Soda ash	1.85	
Copper sulphate	0.62	
Barrett No. 4	0.13	
Cresylic acid	0.20	
Xanthate	0.15	
Concentrates sacked—		
number sacks	227	6,343
Total weight—		
wet pounds	30,055	838,713
dry pounds		
Per sack—		
wet—avg. pounds	132.4	132.3
dry—avg. pounds		

FIGURE 9-10.—Daily mill report, Polaris-Taku Mining Co.

POLARIS-TAKU MINING COMPANY, LTD.

Metallurgical report for September, 1938—based on mill weights and assays

Product	Wet tons	%H_2O	Dry tons	% of total weight	Assay oz. gold	Content oz. gold	% of total gold
Ore received	5720.4	2.70	5,566.5		0.2983	1660.49	
Ore in bins 7 a.m. 9/1	150.0	3.00	145.5		0.3120	45.40	
	5870.4	2.70	5,712.0		0.2987	1705.89	
Less ore in bins 7 a.m. 10/1	0	0	0				
Mill feed	5870.4	2.70	5,712.0	100.00	0.2987	1706.17	100.0
Flotation concentrate			368.63	6.45	4.1750	1539.03	90.2
Flotation tailing			5,343.37	93.55	0.0345	184.35	10.8
Unaccountable (gain)						17.21	1.0

Rates of concentration = 15.5 to 1

Mill operation — 24-hour days = 20.59
Mill operation — % operating time = 97.3
Mill operation — dry tons/24-hour day = 277.4

Concentrates	Wet tons	%H_2O	Dry tons		Assay oz. gold	Content oz. gold	% of total gold
Produced			368.63		4.1750	1539.03	100.0
Sacked	419.3565	10.92	373.63		4.1700	1558.04	101.2
*In thickener, etc.			5.00		3.8060	19.01	1.2

*Thickener has 5.0 tons less than at 9-1-38

FIGURE 9-11.—Monthly metallurgical report, Polaris-Taku Mining Co.

silver, 16.39 percent for zinc, and 18.30 percent for lead. Such a condition leads to speculation about sampling errors.

Polaris-Taku Company.—Reports of the Polaris-Taku Mining Company, Ltd., present views of an entirely different operation. The mill is in British Columbia. The ore, of which the principal mineral is gold-bearing arsenopyrite, was subjected to fine grinding and subsequent flotation of the arsenopyrite. The concentrate was thickened, filtered, and sacked. Concentrates were transported by river barge to the sea, then trans-shipped to an ocean freighter and taken to Tacoma. This type of transportation is unsuited to bulk concentrates; hence, the necessity of sacking.

A daily mill report, with its data, is shown in Figure 9-10; it is also a daily metallurgical and operating report. Data recorded daily in this form are most valuable, for they give a comprehensive picture of both metallurgy and operation. An important feature is the accumulated figures for the month.

The apparent percentage of gold recovered is found by dividing the ounces of gold in the concentrate by the ounces of gold in the feed. Similarly, the ratio of concentration (13.0) is the dry tons of mill feed divided by the dry tons of concentrate.

It is noted that the daily mill report is for September 30 and contains the accumulated data for that month. The latter may now be compared to figures of the monthly metallurgical report for the same month (Fig. 9-11).

The September metallurgical report shows that about 150 tons more ore was treated than received, because the ore bins contained 150 tons on Sep-

JARDINE MINING COMPANY

Metallurgical report—February 1940

Product	Weight: Dry tons	Weight: % total	Assay oz. Au	Content oz. Au	% Recovery Gold
Mill feed	4,505.0	100.0	0.242	1,090.21	100.0
Amalgam plate				482.03	44.2
Plate tails	4,505.0	100.0	0.135	608.18	55.8
Flotation conc.	175.0	3.9	2.609	456.63	41.9
Flotation tails	4,330.0	96.1	0.035	151.5	13.9

Amalgam to retort	1,189.05 troy ounces	
Before melting	571.34 troy ounces	
*After melting (bullion)	571.60 troy ounces	
Gold fineness	831	
Silver fineness	123	
*Amalgam from plates contains		482.03 oz. gold
Actual gold in amalgam		475.00 oz. gold
Unaccountable loss		7.03 oz. gold

FIGURE 9-12.—Monthly metallurgical report, Jardine Mining Company

tember 1 and were empty on October 1. Gold assays of the mill feed, concentrates, and tailings are closely coincident with those shown on the daily mill report for September 30, under the To date column. The sum of gold contents of concentrates and tailings is 1,723.38 ounces or 17.21 ounces more than contained in the mill feed. This is recorded as an unaccountable gain, equal to 1 percent of the total gold in the ore. The origin of Unaccountable (gain) is indicated under Concentrates, where concentrates sacked exceeded concentrates produced by 5 tons. The gain arises from the fact that the concentrate thickener contained 5 tons less of concentrates on October 1 than on September 1.

Jardine Mining Company.—This property is in southern Montana, about 7 miles from Gardiner. Part of the gold in the ore is free; the rest occurs in sulfantimonide, sulfarsenide, and very small quantities of tellurides, in arsenopyrite and quartz. The crushed ore was fed to stamps, which discharged through screens onto amalgamation plates. The plate tails flowed to a classifier in closed circuit with the ball mill, and the finely ground product was subjected to a flotation operation for recovery of the arsenopyrite and its contained gold. The metallurgical report (Fig. 9-12) shows that 44.2 percent of the gold was recovered on the amalgamation plates and 41.9 percent in the flotation concentrates for the total of 86.1 percent. After retorting the amalgam and melting the gold sponge, however, we have 571.60 ounces of gold shown in the amalgam from the plates. Therefore, we have an unaccountable loss of 7.03 ounces of gold, which is 0.64 percent of the total gold in the mill feed.

The flotation concentrate was shipped to the smelter. A roasting and cyanide plant was built to treat the flotation concentrate and to make arsenic trioxide as a byproduct for use as a weed killer.

SETTLEMENT WEIGHTS AND ASSAYS

When paying for the concentrates received, the smelter mails to the shipper a record containing weights and moisture assays together with the 'settlement assays' (those of the umpire assays or those agreed upon between shipper and smelter by 'splits'); the record also shows the amounts of money to be paid for contained metals, the charges for smelting, and the penalties, if any, according to the smelter contract. These figures, weights, metal contents, and money represent the final figures.

Many companies make up two monthly metallurgical balance sheets or reports; the first is based upon mill figures throughout; the second, upon the concentrates weights, assays, and metal or mineral contents according to the smelter settlement sheets.

Smelter contracts and settlements will be discussed in more detail under the heading Economics.

CONCENTRATION CALCULATIONS

Heretofore, **actual weights** and assays have been employed to obtain a metallurgical balance indicating percentages of total weight and metal recoveries in each product. But on many occasions in milling operations, actual weights are not available—only assays. For proper control of the concentration process, methods of calculation have been developed wherein assays alone are needed.

Ratio of Concentration.—The weight of mill feed, divided by the weight of concentrate, is called the ratio of concentration. Referring to Figure 9-8, we have:

Feed (4,014.92 tons) divided by concentrate (335.27 tons) equals 11.97, the ratio of concentration. Also feed (100.00 percent weight) divided by concentrate (8.35 percent weight) equals 11.97, (ratio of concentration) equals 8.35 percent, which (Fig. 9-8) is the concentrate weight expressed as a percentage of the mill feed.

To calculate the Ratio of Concentration using assays only, these abbreviations are used:

H—Weight of mill feed (heads)
C—Weight of concentrate
T—Weight of tails
h—Assay of mill feed
c—Assay of concentrate
t—Assay of tails

Now, according to definition, the ratio of concentration is weight of mill feed divided by weight of concentrate, or

(a) $\frac{H}{C}$ = ratio of concentration = K.

The lead assays in Figure 9-8 show that weight of mill feed times its lead assay equals weight of concentrate times its lead assay plus weight of tails times its lead assay. Stated more simply the lead contents of concentrates and tails equals lead content of mill feed, or:

(b) $Hh = Cc + Tt$

It is also true that weights of tailings plus concentrate equals weight of mill feed:

(c) $H = C + T$

If equation (c) be multiplied by t, the tailings assay, we have:

(d) $Ht = Ct + Tt$

Subtract equation (d) from equation (b)

$Hh = Cc + Tt$

$Ht = Ct + Tt$

$(Hh\text{-}Ht) = (Cc\text{-}Ct) + (Tt\text{-}Tt)$

or (e) $H\ (h\text{-}t) = C\ (c\text{-}t) + 0$

or (f) $\frac{H}{C} = \frac{(c\text{-}t)}{(h\text{-}t)} = K$ (from equation (a))

Substituting the lead assays of Figure 9-8 (metallurgical balance) in equation (f):

$$\frac{H}{C} = \frac{64.70 - 0.81}{6.50 - 0.81} = 11.23 = K$$

Because of the unaccountable loss, the figure for K (11.23) does not coincide with the 11.97 for K obtained from weights. If we substitute lead assays from the 'Metallurgical report—using concentrates and tailings', Figure 9-8, we have:

$$K = \frac{(c-t)}{(h-t)} = \frac{64.70 - 0.81}{6.14 - 0.81} = 11.99$$

Percentage of Recovery.—The pounds, ounces, or other units of metal recovered in a concentrate, expressed as a percentage of the pounds, ounces, or other units of that metal in the mill feed, is the recovery. More simply, units of metal in the concentrate divided by units of that metal in the mill feed multiplied by 100 is the percentage of recovery or:

$$\text{(g) } \% \text{ recovery} = \frac{Cc}{Hh} \times 100 = R$$

From equation (f) $\frac{H}{C} = \frac{(c-t)}{(h-t)}$, and therefore

$$\text{(h) } \frac{C}{H} = \frac{(h-t)}{(c-t)}$$

Substituting for $\frac{C}{H}$ from (h) in equation (g) we have:

$$\text{(i) } \frac{c\ (h-t)}{h\ (c-t)} \times 100 = R$$

Applying the lead assays of the metallurgical report, Figure 9-8, in equation (i):

$$\frac{64.70\ (6.14 - 0.81)}{6.14\ (64.70 - 0.81)} \times 100$$

equals

$$\frac{64.70 \times 5.33}{6.14 \times 63.89} \times 100$$

equals

$$\frac{344.85}{392.20} \times 100 = 87.91\% \text{ Recovery,}$$

which agrees with the actual figure of 87.9

It is obvious that for correct results, the sampling and assaying of mill feed and products must be accurate, as the calculations will reflect any errors in either.

To this point, lead assays from Figure 9-8 have been employed to check reliability of formulas, although the silver assays could also have been substituted. When calculating ratios of concentration, use those assays that have the greatest degree of accuracy.

Heretofore, only a two-product concentration has been considered; concentrate and tailing. A three-product concentration, such as lead concentrate, zinc concentrate, and tailing, can be calculated in the same manner as shown above, if two assays are available, such as lead and zinc or lead and silver. The formulas are long and involved, and reflect the errors of assaying and sampling. A simpler and perhaps better method is to sample the lead section tails; then make two sets of calculations, using formulas (f) and (i) for both lead and zinc concentrates, and substituting lead assays first as a check against zinc assay results, as exemplified in the following:

Product	% Weight	Assays % Zn	% Pb
Mill heads	100.00	5.00	3.00
Lead conc.	5.10	3.30	50.20
Lead tail.	94.90	5.09	0.46
Zinc conc.	8.80	50.00	2.05
Zinc tail.	86.10	0.50	0.30

Lead concentrate

First, use lead assays, in formulas (f) and (i) for Lead Concentrate.

$$\text{(f) } \frac{50.2 - 0.46}{3.0 - 0.46} = \frac{49.74}{2.54} = 19.58$$

equals

ratio of concentration

$$\text{(i) } \frac{50.2\ (3.0 - 0.46)}{3.0\ (50.2 - 0.46)} \times 100$$

equals

85.4% of lead recovered in lead concentrate.

Second, use zinc assays in formulas (f) and (i).

$$\text{(f) } \frac{3.3 - 5.09}{5.00 - 5.09} = \frac{-1.79}{-0.09} = 19.89$$

equals

ratio of concentration

$$\text{(i) } \frac{3.3\ (5.00 - 5.09)}{5.00\ (3.3 - 5.09)} \times 100$$

equals

$$\frac{-0.297}{-8.950} \times 100$$

equals

3.32% of total zinc recovered in lead concentrate.

Zinc concentrate

First, use zinc assays in formulas (f) and (i).

$$\text{(f) } \frac{50.0 - 0.50}{5.09 - 0.50}$$

equals

$$\frac{49.50}{4.59} = 10.78$$

equals

ratio of concentration considering lead tails to be the heads of the zinc section.

However, lead tails have but 94.9 percent of the original ore weight, so the actual ratio of concentration is 10.78/0.949 = 11.36

$$\text{(i) } \frac{50.0\ (5.09 - 0.5)}{5.09\ (50.0 - 0.5)} \times 100$$

equals

91.1% of zinc recovered in zinc concentrate, with lead tails as the feed to zinc section. But from above, 3.36 percent of the total zinc is in lead concentrate; and it follows that lead tails have 96.64 percent of the total zinc in the ore.

Therefore, true percentage of zinc recovered in zinc concentrate is 91.1% × 0.9664 = 88.0%.

Second, use lead assays in formulas (f) and (i).

$$\text{(f) } \frac{2.05 - 0.30}{0.46 - 0.30} = \frac{1.75}{0.16} = 10.94$$

equals

ratio of concentration with lead tails as feed to zinc section. From lead concentrate calculations, ratio of concentration for lead concentrate is 19.89; 19.89 = 5.03 percent of total ore weight. Lead tails then have 100 — 5.03 = 94.97 percent of total ore weight. Therefore, the true ratio of concentration is 10.94/0.9497 = 11.52.

(i) $$\frac{2.05\ (0.46 - 0.30) \times 100}{0.46\ (2.05 - 0.30)}$$
equals

40.75% of lead recovered in zinc concentrate with lead tails as feed to zinc section.

But, from lead concentrate calculations, the lead concentrate contains 85.4 percent of total lead in the ore. Thus, lead tails necessarily have 100.0 — 85.4 = 14.6 percent of total lead in ore. Therefore, the true recovery of lead in the zinc concentrate is 40.75% × 0.146 = 5.95%.

Summarizing calculated results:

	Lead conc.	Zinc conc.
Ratio of concentrate—Actual	19.61	11.36
Ratio of concentrate—Using lead assays	19.58	11.52
Ratio of concentrate—Using zinc assays	19.89	11.36
% Recovery of lead—Actual	85.30	6.00
% Recovery of lead—Lead assays	85.40	5.95
% Recovery of zinc—Actual	3.40	88.00
% Recovery of zinc—Zinc assays	3.32	88.00

When you attempt to calculate weights and recoveries from a concentration operation in which three or more products are made, accurate assays must be available. The number of assays may be one less than the number of products.

Taggart* showed the use of determinants for solving these problems.

COST ACCOUNTING

As in any well-run business enterprise, mineral benefication plants should maintain adequate cost record systems, not only for checking and preventing losses, but to reduce operating costs. For smaller plants, the cost accounting systems may be relatively simple, under such headings as: Labor, Power, Supplies, Haulage, Repairs and Maintenance, Overhead, and Taxes.

If operations are such that more details are required, the main divisions are changed to: Coarse crushing, Fine crushing, Grinding and classification (ball mill and classifier), Flotation, Concentrate dewatering, Tailings disposal, Concentrate haulage, and General expenses.

Under the detailed system, water, power, and labor become redistributables. First, a water survey of the plant is made and water costs allocated on the basis of the use by each section. Installed horsepower for each section is the basis for power distribution; and, of course, labor is distributed according to occupation.

If further refinements are needed, code or account numbers are employed as indicated on the following system tabulation. This system is capable of infinite extension. For example, under coarse crushing, cost records of each individual machine — crushers, conveyors, elevators — could all be maintained but with corresponding increase in cost record personnel. If concentrates are hauled by truck to the railroad, it is usual to assess these transportation costs against mill operation. The railroad freight costs to the smelter are commonly charged to the smelting operation, because the smelter generally pays the freight and deducts it from the amount due the shipper. If the milling plant hauls its concentrates to the smelter from the mill in its own trucks, the cost is charged to mill operation, because the smelting company does not pay the freight.

ACCOUNT SYSTEM

Code or account no.

100—Coarse crushing
- 101 Labor
- 102 Power
- 103 Supplies
- 104 Repairs
  - a. Parts
  - b. Labor
- 110 Water

200—Fine crushing
- 201 Labor
- 202 Power
- 203 Supplies
- 204 Repairs
  - a. Parts
  - b. Labor
- 210 Water

300—Grinding and classification
- 301 Labor
- 302 Power
- 303 Repairs
  - a. Parts
  - b. Labor
- 304 Supplies
- 305 Supplies—balls
- 306 Supplies—liners
- 310 Water

*Taggart, A. F., 1945, Handbook of mineral dressing, p. 19-192, John Wiley & Sons, New York, New York.

Code or account no.

400—Flotation
- 401 Labor
- 402 Power
- 403 Supplies
- 404 Repairs
  - a. Parts
  - b. Labor
- 407 Supplies—reagents
- 410 Water

500—Concentrate dewatering
- 501 Labor
- 502 Power
- 503 Supplies
- 504 Repairs
- 510 Water

600—Tailings disposal
- 601 Labor
- 602 Power
- 603 Supplies
- 604 Repairs

MINERALS ENGINEERING CO. **TIME CARD** Shift No.________

Employee____________________ Date____________ Rate________

Hours	Description of Work	Code No.						

Signed____________________ Approved____________
Employee Foreman

FIGURE 9-13.—Form for daily time card.

MATERIALS & SUPPLIES FROM STOCK

Date____________________

For Code No.	Weight or Number	Description
		Authorized by____________________

FIGURE 9-14.—Requisition for supplies.

700—Concentrate haulage

701 Labor
702 Power
703 Supplies
704 Supplies—gasoline or diesel fuel
705 Repairs

800—Sampling

801 Labor
802 Power
803 Supplies

900—Assaying

901 Labor
902 Power
903 Supplies—general
905 Repairs

1000—General expense

1001 *Superintendence
1002 Clerical, office personnel
1003 Office supplies
1004 **Lighting
1005 **Heating
1006 Lubrication
1007 ***Industrial Accident Board
1008 ***Unemployment Compensation
1009 ***Social Security Taxes
1010 Pension and health insurance
1011 Insurance (building and plant)
1012 Taxes
1013 Miscellaneous

*Mill superintendents, mill foremen, metallurgists.
**Both of these accounts may also be redistributables in the several sections, accounts No. 100 to 1000 inclusive.
***In most accounting systems, the employer's contribution to Industrial Accident (Worker's Compensation), unemployment compensation, and Social Security Taxes are classified under General Expense. In others, these are redistributed with labor in the various accounts.

LABOR

The time card is the initial record. On it the employee writes his name, the date, shift, code number, and occupation, with the number of hours for each. These data are transferred to payroll sheets; the employees' names may be listed alphabetically, or segregated according to code numbers for convenience in cost accounting. Specimens of time cards and payroll sheets are incorporated in the following pages.

Federal and state laws require that some taxes be withheld, e.g., income and social security taxes. Therefore, the payroll sheets must record all such payments and deductions, together with the Social Security number of the employee. The payroll sheets are not reported to the government. Instead, quarterly totals are reported. Also, annual reports must be made to state and federal governments giving employee names, Social Security numbers, gross wages paid during the year, and deductions.

Page ______ PAYROLL FOR PERIOD ______ TO ______ Date payable ______

Employee Name	Code no.	Hours worked	Rate per hr.	Earnings			Deductions				Net paid	
				Regular time	Over-time	Total earn.	FICA tax	Feder. tax	State tax	Total deduct.	Net amount	Check no.

FIGURE 9-15.—Payroll form

Because quarterly and annual reports of each employee's earnings are required, a payroll sheet for the individual is a necessity.

To arrive at the total labor cost, additional items, called payroll taxes, must be added: employer's half of Social Security payments, Industrial Accident Board assessment, insurance and pension plan, if any (see Chapter 6).

Industrial Accident Board assessments are based on the payroll. Rates vary with job classification and with state of residence, and can be expected to range from a fraction of one percent for office employees to 10 percent or more for relatively hazardous occupations. Specific rates can be obtained from the State Industrial Accident Board of the state in which the plant is located.

Unemployment compensation is payable quarterly to the Unemployment Compensation Commission. Again rates will vary, and in addition, a contribution is also claimed by the U.S. Internal Revenue Service, currently figured at 0.58 percent of the gross payroll.

The Old Age Benefit or Social Security Tax (F.I.C.A. Tax) must also be included in total labor cost, and is currently 11.7 percent of the gross payroll to a maximum of $14,100 per year, half of wh'ch (5.85 percent) is paid by the employer and half is deducted from the employees' wages. The contribution rate will increase to 6.05 percent in 1978.

For the most part, small mineral beneficiation plants do not carry pension plans of any kind. Occasionally, plans calling for 3 to 5 percent contributions (based on gross payroll) by employer and employee may be effected. Similarly, joint premium payments by employer and employee may be used for life, health, and accident group insurance plans.

POWER

Depending on location, the milling plant may purchase its power from a public service corporation (such as Montana Power Company) or produce its own power from a diesel-electric installation, or if sufficient water is available, install a hydroelectric plant. With proper conditions of elevation and an ample water supply during all the year, a hydroelectric plant produces the cheapest electric power. Power purchased from a public service corporation is likely to be less costly than diesel-electric power.

For most milling plants, purchase of electric power from a public service corporation is the best solution for the power problem. Considerable capital expense is avoided, even though several miles of power line must be built. If the power line is long, however, then its cost must be balanced against that of the diesel-electric installation. When a milling plant or mine is several miles distant from an electric power distribution point, the milling company may either build the power line or pay its cost to the electric power company. The power company will then deduct 20 percent from each of its monthly bills until the accumulated sum of these deductions is equal to the cost of the power line. Ownership of the power line then passes to the power company.

The Montana Power Company is the chief producer of electric power in Montana. Its open schedule GS-72 is shown as an example. The rates are in two parts; first, the kilowatt hour charges (KWH); second, the kilowatts for power charge. The latter is commonly called a demand power charge.

To clarify the method of calculating electric power costs from the schedule, a power bill is shown, together with its calculations.

Only those mills in extremely isolated locations are forced to build their own power plants. Most of these are diesel-electric installations, for very few have the requisite conditions for hydroelectric power generation. Accurate data concerning these are most difficult to obtain, as many of the operations carry no cost records. The Polaris-Taku Mining Company, Ltd., of British Columbia generated electric power with both diesel- and hydroelectric plants. Their records are excellent examples of careful and businesslike accounting practices. Electric power expense records for periods of 1 month and 8 months are shown on Figure 9-18. For the 8-month period, hydroelectric cost per kilowatt hour is about one tenth that of diesel-electric power. Although these figures are old, they afford a good example of relative cost.

Power cost may be distributed on either of two methods: (1) horsepower hours (installed horsepower times hours a run), or (2) kilowatt hours (from power consumption figures). The latter method is illustrated by the following tabulation.

SUPPLIES

From a cost viewpoint, the housing and distribution of the many supply items needed by a milling plant are most important. Each item should have a definite, well-marked location and should be obtained either by warehouse requisition or by authorization in writing by a responsible employee, such as mill foreman or shift boss. Screws, nails, bolts and nuts, electrical and pipe fittings, electric wiring, and all other small supply parts should be in well-marked compartments or locations. Spare motors and motor parts should be covered to avoid dust and water damage. Heavy parts, such as crusher mantles and liners and ball mill liners, should be placed as close to their respective machines as convenient. Balls should be stored in covered bins according to size. Covered, moisture-proof storage space should be provided for 'reagents' especially those sold in paper bags. Quantities used each day are entered on the mill

Form 403-B

Public Service Commission of Montana

THE MONTANA POWER COMPANY

(Name of Company)

Sheet No. GS-72

Cancelling Sheet No. GS-69

Schedule GS-72

GENERAL ELECTRIC Service

AVAILABLE FOR: All electric service required when supplied through one meter at one point of delivery. Not available for standby, breakdown, resale or shared service.

TYPE OF SERVICE: Sixty cycle alternating current at such phase and voltage as Company may have available.

RATE: Net monthly bill:

First	20	kwh or less per month for $1.40.	
Next	80	kwh per month @	4.44¢ per kwh
Next	1700	kwh per month @	3.77¢ per kwh
Next	3200	kwh per month @	2.22¢ per kwh
Next	15000	kwh per month @	1.22¢ per kwh
Next	200	kwh per kilowatt of demand per month @	1.00¢ per kwh
All additional kwh @			0.67¢ per kwh

PLUS

First 10 kilowatts -- no charge
Next 20 kilowatts -- $1.33 per kilowatt
All additional kilowatts -- $1.11 per kilowatt

MINIMUM BILL: $1.40 per month

TAX ADJUSTMENT CLAUSE: The Company may increase the bill for electric service supplied under this Schedule by an amount equal to the proportionate part of any taxes other than those in effect on November 1, 1972, subject to the prior approval of the Montana Public Service Commission.

DETERMINATION OF KILOWATTS: The average kilowatts supplied during the 15-minute period of maximum use during the month, as determined by permanently installed indicating type meter.

SPECIAL TERMS AND CONDITIONS: (1) Customer may be required to pay the cost of installing and removing all the facilities required to supply seasonal and short-term service. Customer must pay the cost of installing and removing all the facilities required for rendering temporary service; and (2) Supplementary service may be supplied by the Company only under special contract specifying the rates, terms and conditions governing such service. (3) The Electric Service Regulations on file with the Public Service Commission are part of this schedule.

Issued September 15, 1972 (Date) By /s/ J. W. Heidt (Signature of Officer of Utility)

Approved September 15, 1972 (Date) Effective On all meter readings on and after October 17, 1972 (Date)

(Space for Stamp or Seal of Commission)

PUBLIC SERVICE COMMISSION OF MONTANA.
/s/ Patricia Sheehan
Secretary.

*Space below these lines for use of Commission only.

FIGURE 9-16.—Open Power Schedule.

POWER BILL To: EG. Gold Corporation

85760 KWH $1091.30

November 30, 1974 Demand KW = 189

Calculation

	85760		
less	20	at $1.40	1.40
	85740		
less	80	at 4.44¢	3.55
	85660		
less	1700	at 3.77¢	64.09
	83960		
less	3200	at 2.22¢	71.04
	80760		
less	15000	at 1.22¢	183.00
	65760		
less	*37740	at 1.00¢	377.40
and	28020	at 0.67¢	187.73
Total	85760	at 1.035¢	888.21
	Total demand = 189 KW		
	less 10 KW		0.00
	179		
	less 20	at $1.33	26.60
	and 159	at $1.11	176.49
	Total		203.09
		Grand Total	1091.30

Actual cost per KWH = 1091.30 ÷ 85760 KWH = 1.272¢

*188.7 × 200 = 37740 KWH

FIGURE 9-17.—Example of a power bill, EG. Gold Corporation.

report either by the reagent man or by the shift boss. A supply card may be used for the same purpose. Assay office supplies and chemicals should be placed for convenience in a room forming a part of the assay office.

Supply cards may have these headings: Code no. or machine, name of part, number of part, date, and a place for the signature of the employee. Items from the supply cards are entered daily upon accounting sheets, according to code numbers or classification, and extensions of number and price are made. Typical examples of supply cards and accounting sheets are shown in Figures 9-20, 9-21, and 9-22.

In some plants, it is customary to maintain a running inventory of supplies. The quantities of each item on hand at the beginning of an accounting period are entered on stock record sheets. Then, daily quantities of items used are subtracted for the new 'on hand' figures. It is good practice to make an inventory of supplies at the beginning or end of each month (or other accounting period) as a check on the accuracy of supply card quantities. The weight or number and the cost of supplies are totaled each month for each classification. The stock record cards have the quantities of each and every item used during the month, and their running inventories should agree with the actual physical inventory.

POLARIS-TAKU MINING COMPANY, LTD.

Electric Power Expense

for month of December 1938 and accounting period to end of month

	Month	Period—8 months
KWH's from diesel engines (Crossley)	129,450	263,600
KWH's from hydro plant	104,000	1,668,000
Total KWH's generated	233,450	1,931,680
Diesel engines (Crossley):		
Labor—operating	$ 181.84	$ 808.52
Diesel oil	1,279.09	3,178.66
Lubricants	77.90	269.67
Repairs—labor and shop expense	92.50	429.34
—supplies	324.74	431.40
Workmen's C.B.	10.21	42.70
Miscellaneous	25.87	45.85
Total diesel engines	1,992.15	5,206.14
Hydro plant:		
Labor—operating	89.17	936.86
Tending dam—labor	320.00	2,004.70
—supplies	....	6.49
Repairs—labor	7.50	277.49
—supplies	21.30	284.83
Miscellaneous (deferred a/c)	158.15	693.55
Workmen's C.B.	16.67	121.89
Water rights expense	4.10	44.22
Total hydro plant expense	616.89	4,370.03
Total electric power	2,609.04	9,576.17
Average cost per KWH—diesel engines	1.539 cts.	1.975 cts.
Average cost per KWH—hydro plant	.593 ct.	0.262 ct.
Average cost per KWH—all electric power	1.118 cts.	0.496 ct.
KWH's produced by diesel per gallon of fuel oil	13.636	11.525

FIGURE 9-18.—Comparison of power costs, diesel vs. hydro-electric, Polaris-Taku Mining Co.

EG. GOLD CORPORATION
Distribution of electric power by department

Average cost/KWH for all electric power 1.27¢

	Period — 8 Months			
	Estimated		Per ton mill feed	
	KWH	Amount $	KWH	Amount $
MILL:				
Crushing	29,200	371.60	1.903	0.024
Grinding and classification	259,944	3,307.76	16.949	0.216
Flotation	90,776	1,155.12	5.918	0.075
Dewatering	11,344	144.32	0.740	0.009
Lighting	19,496	248.08	1.270	0.016
Total mill	410,750	5,226.88	26.780	0.340
Air compressor	242,600	3,087.04	15.818	0.201
Surface lights	1,632	20.72	0.107	0.001
Bunkhouse and dry	5,608	71.36	0.366	0.005
Assay office	2,640	33.60	0.172	0.002
Machine shop	8,912	113.44	0.581	0.007
Carpenter shop	3,928	50.00	0.256	0.003
Blacksmith shop	1,864	23.68	0.122	0.001
Mess operations	2,272	28.88	0.148	0.002
Mine	5,864	74.64	0.382	0.005
Total	686,070	8,730.24	44.732	0.567

FIGURE 9-19.—Example of power distribution by departments, EG. Gold Corporation.

HAULAGE

For mineral beneficiating plants, costs begin at the primary ore bins. For that reason, haulage generally refers to transportation of concentrates from the mill to the railroad or a smelting plant. If the quantities of concentrates shipped are small and the distance not great, the milling company may find that use of its own truck or trucks will be advantageous. If quantities of concentrates produced are great or the distance considerable, the haulage may be let on contract. Such contracts are usually written on a 'price per ton mile' basis, the price depending on the distance, road conditions, and other factors. Because conditions are so variable, it is impossible to give an average haulage cost. For example: a plant producing 50 tons of concentrates a week should have ample storage for that quantity, and should ship once a week. A distance of 5 miles over a good road might call for a price per ton mile of 20 cents, making a $1.00 cost per ton of concentrates. A similar mill 10 miles from the railroad and with a poor road may have a cost of 50 cents per ton mile or $5.00 per ton.

REPAIRS AND MAINTENANCE

Plant building repair and maintenance is usually listed under general expense. It includes painting, re-roofing, plumbing, wall repairs, electrical and miscellaneous.

OVERHEAD

Overhead is a very elastic classification, and its boundaries are ill defined. When mining and milling operations are performed by the same company, the term overhead may include the salaries of corporation officers, such as president, vice president, secretary, and manager, main office rental (if in town), and clerical salaries.

GENERAL EXPENSE

General expense is a 'catchall' for all classifications that cannot be conveniently assigned to other departments. The account system table has a list of thirteen items, most of which are self-explanatory.

Taxes (Account no. 1012) are here limited to property and net proceeds or corporation license taxes. They do not include federal income taxes on net earnings.

SUPPLY RECORD

Account No. 303 — **Description Grinding and classification**

Date	No. or wt., lb.	Item	Size	Unit cost	Amount $
	500	Balls	4"	0.14	70.00
	700	Balls	4"	0.14	98.00
	6	Bolts	8 x 1¼"	1.40	8.40
	10	Class flights		1.80	18.00

FIGURE 9-20.—Example of departmental supply record.

ARTICLE ________

	RECEIVED						ISSUED			ON HAND		
Date	Order no.	Quantity	Invoice price	Freight	Total	Unit price	Req. no.	Quantity	Amount	Quantity	Unit price	Amount

FIGURE 9-21.—Example of stock record card.

MONTHLY OR PERIOD COST REPORTS

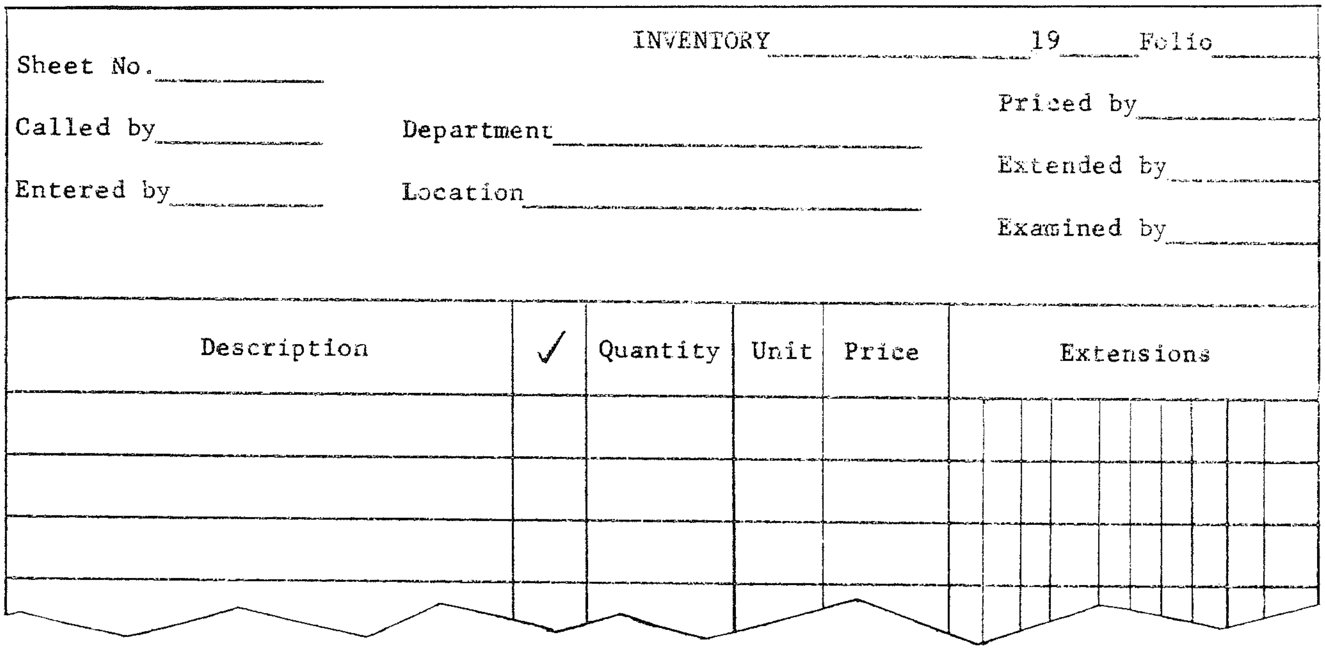
Cost reports comprise labor, supplies, power, and all other expenses totaled and distributed among the various classifications or departments. These records are indispensable for the proper control of milling operations, because they afford the sole means of comparing periodic figures for correcting losses and reducing costs.

A table (Fig. 9-23) is presented to provide some idea of the total cost of milling a ton of ore, and the effect that more than 40 years of inflation has had on this cost. It must be emphasized, however, that actual cost at any given mill may vary widely from these figures. The examples given are for small mills, processing a few hundred tons of ore per day, including crushing, grinding, flotation, dewatering, and tailings disposal. Cost variations may result from such factors as ore complexity, degree of grinding required for liberation, mill location with respect to water and power supply, unit power cost, and many others.

Another example is provided in Figure 9-24. In this example, costs are presented in greater detail, which can be extremely useful in detecting excessive costs so that corrective measures can be taken. Again, the example given is intended to provide an idea of relative cost, not exact current costs. The example would apply for a mill of 400 to 500 tons per day capacity. For mills of smaller capacity, labor costs can be expected to account for a greater percentage of total cost, whereas other items will account for a lesser percentage. Thus, in a small mill processing less than 100 tons per day, labor cost might be as much as half of the total cost per ton. Total per ton costs are also sensitive to capacity, ranging from $4 or $5 for very small mills, to $1 or less in plants of very large capacity.

ECONOMICS

In its broadest sense, economics is a science that investigates conditions and laws affecting production, distribution, and consumption. For the present purpose, economics means determination of a type of mineral beneficiation or metallurgy that will give greatest monetary returns from an ore, or whether the erection of a minerals-beneficiation plant is justified. Such a determination involves estimates of production costs, metallurgy, receipts from sale of products, and capital costs. Production costs involve estimates of labor, supplies, power and water, taxes, and lights. Metallurgy is based on results of small-scale testing of the ore, which should indicate the quantities and qualities of products together with mineral or metal recoveries in each. Estimating receipts from sale of products requires a knowledge of smelter schedules and freight and haulage rates. Capital costs refer to estimates of foundation and building costs, equipment and installation, water and


Sheet No.____ INVENTORY ____ 19 ____ Folio ____

Called by ____ Department ____ Priced by ____

Entered by ____ Location ____ Extended by ____

Examined by ____

Description	✓	Quantity	Unit	Price	Extensions

FIGURE 9-22.—Example of stock inventory card.

power supplies, etc. These figures are important, because the capital cost must be amortized over the anticipated life of the mine and used as a debit for each ton of ore milled. Metallurgical accounting and cost accounting have already been discussed. Before engaging in a discussion of economics, it may be well to comment briefly on smelter schedules.

Before concentrates can be shipped to the smelter, it is customary to submit samples, either from production or from metallurgical tests, together with information as to expected rate of shipment in tons, and to request a schedule of payments and charges therefor. After complete analyses of the concentrates or ore samples, the smelter will supply the information, either in the form of a contract or schedule. Smelter schedules are discussed in Chapter 10, and examples of typical schedules are presented. Although specific charges will vary with world economic conditions, smelter location, and changes in labor cost and metal price, the general form of smelter schedules has not changed much over the years, and they will probably continue in similar form in the future. Perhaps the most important fact for the small-mine operator to keep in mind is that contract negotiations with the smelter for acceptance of concentrates or ores must be completed before shipments can be made. For each producer, the terms and conditions may differ somewhat from those given another producer of a like product, possibly because of tonnage differences, or presence of some undesirable element.

	Cost $/ton		
Item	**1940***	**1969****	**1974*****
Crushing	0.169	0.27	0.38
Grinding and classification	0.300	0.70	1.02
Flotation	0.556	0.77	1.09
Concentrate dewatering	0.053	0.15	0.21
Tailings disposal	0.048	0.12	0.17
Power	0.251	0.34	0.48
Sampling and assaying	0.060)	0.32	0.45
Light, heat, and water	0.263)		
Total	1.70	2.67	3.80

*From Griswold, 1964
**From SME Handbook, 1973 (p. 28)
***Projection based on cost price index increases.

FIGURE 9-23.—Inflation effect upon per-ton cost of milling.

Ore milled: 400 T/D

Acct. no.	Account	Amount	Amount/ton	% Total cost
100	Crushing			
101	Labor	56.000	0.140	
102	Power	12.000	0.030	
104	Repairs and maintenance	24.800	0.060	
103	Supplies	33.600	0.084	
	Subtotal	126.400	0.316	11.099%
300	Grinding and classif.			
301	Labor	95.200	0.238	
302	Power	71.200	0.178	
303	Repairs and maintenance	18.800	0.047	
304	Supplies	108.400	0.271	
	Subtotal	293.600	0.734	25.782%
400	Flotation			
401	Labor	54.400	0.136	
402	Power	30.000	0.075	
404	Repair and maintenance	79.600	0.199	
403	Supplies	144.000	0.360	
	Subtotal	308.000	0.770	27.046%
500	Dewatering			
501	Labor	40.800	0.102	
502	Power	2.800	0.007	
504	Repair and maintenance	4.000	0.010	
503	Supplies	12.400	0.031	
	Subtotal	60.000	0.150	5.269%
600	Tailing disposal			
601	Labor	25.600	0.064	
602	Power	1.200	0.003	
604	Repair and maintenance	10.400	0.026	
603	Supplies	6.800	0.017	
	Subtotal	44.000	0.110	3.864%
1000	General expense			
1001	Superintendence	188.000	0.470	
1004	Lighting	6.800	0.017	
1010	Water	40.000	0.100	
900	Assay laboratory	44.000	0.110	
1005	Heating	4.000	0.010	
1013	Supplies and miscel.	24.000	0.060	
	Subtotal	306.800	0.767	26.941%
	Total	1,138.800	2.847	100.001%

FIGURE 9-24.—Example of mill cost balance sheet.

Item	Amount/ton	Percent
Superintendence and overhead	0.470	16.51
Labor	0.680	23.88
Power	0.293	10.29
Repairs and maintenance	0.344	12.08
Supplies	0.823	28.91
Light and heat	0.027	0.95
Water	0.100	3.51
Assay office	0.110	3.86
Total	2.847	99.99

FIGURE 9-25.—Example of mill cost totals.

CUSTOM ORE PURCHASING SCHEDULES

It sometimes happens that a milling plant obtains its base ore supply from a mine or mines it controls, and that it also has excess capacity. In such event, the milling plant seeks an additional ore supply approximately equal to the deficiency. This may come from one or several mines, and the mill becomes, in effect a custom plant.

In the purchasing of custom ores, two main factors must be considered: (1) concentrate weights, assays, and metal recoveries, obtained by laboratory tests upon a representative sample of the ore; and (2) an accurate knowledge of mill operating cost.

The laboratory tests must parallel mill operations very closely, particularly in fineness of grind, types of gravity and flotation machines, and flotation reagents.

As to milling costs, it has been assumed that the tonnage of base ore supply that the mill controls is considerably less than mill capacity and that the mill operating cost is accurately known. To use the excess capacity requires no additional mill personnel; thus, if a mill is operating at full capacity, operating costs per ton are reduced.

Some operators have reasoned that the treatment of additional ore does not involve the expenditure of more dollars; therefore, the treatment cost of the additional ore is nil, and the operator can make a very favorable treatment charge to obtain the ore. To illustrate: Mill is treating 300 tons daily at a cost of $4 per ton. It has a capacity of 400 tons daily. Under the premise that the treating of 100 tons additional does not increase the total operating cost of $1,200 daily, then theoretically, the mill is treating 100 tons daily at a cost per ton of $0. We have then:

300 tons × $4 = $1,200
100 tons × $0 = $0.000

400 tons × $3 = $1,200

Therefore, the treatment charge for the whole has been reduced from $4 for a 300-ton rate to $3 for a 400-ton rate. If the additional ore is particularly desirable, either from a tonnage or quality viewpoint, the mill operator may desire to sacrifice gains through the treatment charge. He may reduce the charge from $4 to any point between that and $0 as necessity may demand. He obtains profits in the difference between purchase price of the ore and the combined net returns of the concentrates produced from it.

Against the premise that excess tonnage may be treated at no cost, it may be said that fixed per ton charges such as crusher liners, ball mill liners, balls consumption, as well as some power, cannot be disregarded. But, in sum, these are small and will not greatly affect a sizable reduction in treatment charges.

RAILROAD FREIGHT RATES

The freight rates published by the different railroads have been approved by the Interstate Commerce Commission or the State Public Service Commission. Rates vary according to distance and the value of the product being shipped. Published freight rates for a particular product may be too great to permit its economic disposal. If a fairly large tonnage is to be shipped, the railroad involved may forward approval for a lower freight rate to the appropriate Commission committee.

Published rates for transportation of ore or concentrates by rail from the mill loading dock to the smelter will be provided by the railroad involved, upon application. If the transportation involves a transfer from one railroad to another, there is an additional switching charge.

TRUCK HAULAGE RATES

Main highways follow railroad routes to a great extent, and truck operators compete with the railroads for the transportation of heavy or bulky materials. For a distance less than 500 miles, truck operators may offer a lower rate than the railroads for transportation of concentrates, particularly if a back-haul is involved. Many transportation contracts with truck operators provide for delivery of concentrates to the trucks at the milling plant, which may be several miles from the main highway. The railroads do not offer such a service.

APPLICATIONS OF SMELTER AND MILLING SCHEDULES

All needful elements, such as schedules, freight rates, product weights, and assays are now at hand for calculation of the net values of various concentrates and ores. Two examples follow:

1. Copper Concentrates: Flotation milling of a gold-copper ore gave the following products:

	Assays				% Distribution		
Product	**% Weight**	**Oz. Au**	**Oz. Ag**	**% Cu**	**Au**	**Ag**	**Cu**
Mill feed	100.0	0.30	0.60	1.00	100.0	100.0	100.0
Concentrate	4.8	4.54	8.10	18.46	72.7	64.8	88.6
Tailings	95.2	0.07	0.20	0.12	22.3	31.7	11.4
Unaccountable	—	—	—	—	6.3	3.5	0.0

Concentrates are shipped to a copper smelter according to the terms of the smelter schedule presented in Chapter 10. Metal prices for the period are assumed to have been: gold, $177.75/ounce; silver, $4.21/ounce; copper, 63.6¢/pound. It is also assumed that these metals are not contained in arsenical or antimonial minerals, hence there is no penalty charge for those ingredients.

Payments:	Credits
Gold—4.54 oz; pay for 4.18 oz @ $177/oz	$739.86
Silver—8.1 oz; pay for 7.10 oz @ $4.15/oz	29.47
Copper—18.46%; pay for 340.47 lb. @ 56.02¢/lb	190.73
	$960.06
Deductions:	
Base charge	$ 35.00
Net smelter return per dry ton of concentrate	$925.06
Net smelter return per dry ton of ore (925.06 × 0.048)*	$ 44.40
Less freight, taxes, and assay charges.	

*The factor 0.048 is derived from the fact that the concentrate is 4.8% by weight of the mill feed (see table).

2. Lead Concentrates: Milling of a fairly complex ore produces the following products:

	Assays					% Distribution			
Product	**% Wt.**	**Oz. Ag**	**% Pb**	**% Cu**	**% Zn**	**Ag**	**Pb**	**Cu**	**Zn**
Mill feed	100.0	10.00	4.00	0.10	2.50	100.0	100.0	100.0	100.0
Concentrate	9.0	93.33	37.78	0.87	1.53	84.0	85.0	78.0	5.5
Tails and Unaccountable	91.0	1.76	0.66	0.02	2.59	16.0	15.0	22.0	94.5

Concentrates are sent to the lead smelter whose schedule is presented in Chapter 10. Metal prices are assumed to be: silver, $4.21/ounce; lead, 24.5¢/pound; copper, 63.6¢/pound. Note: copper is retained in the concentrate because it contains a significant proportion of the silver in the ore. Zinc is not retained, because no payment is made for zinc at any plant within practical shipping distance of the mill.

Payments:	Credits
Silver—93.33 oz; pay for 87.7 oz @ 4.08/oz	$357.82
Lead—37.78%; pay for 689.3 lb @ 19.8¢/lb	136.48
	$494.30
Deductions:	
Base charge	$ 35.00
Net smelter return per dry ton of concentrate	$459.30
Net smelter return per dry ton of ore (459.3 × 0.09)	$ 41.34
Again, less freight, taxes, and assay charges.	

CAPITAL COSTS

A brief generalization of capital costs is in order, because they will be employed later for amortization and depreciation purposes. These remarks are not to be taken as guides to construction costs, except in a very broad sense.

	$/ton daily mill capacity	
300/400 tons daily capacity	1964	1974
Crushing, fine grinding, flotation, and dewatering	2,500	7,000
Coarse crushing, rod mill grinding, and gravity concentration	1,800	5,000
Cyanidation of gold ores, fine grinding, and agitation	2,500	6,000
Cyanidation of gold ores, coarse crushing and leaching	1,250	3,500

FIGURE 9-26.—Comparative capital costs.

The figures for capital costs include water supply, if the distance between the source and the mill is not excessive. Also included are costs of transformers; the power lines are excluded. Initial costs of building the tailings dams are covered.

ESTIMATES

The several factors controlling the financial aspects of a milling operation have been discussed in greater or lesser detail. Data are at hand from which estimates may be made—estimates to ascertain profits or losses from the proposed milling enterprise; estimates to justify capital expenditures for additions or alterations; calculations to indicate whether or not an ore should be concentrated or shipped directly to the smelter.

Problem 1. Should an ore be shipped directly to a smelter, or should the ore be concentrated at or near the mine?—The factors affecting the decision are:

1. Grade of ore (quality)
2. Ore reserve (quantity)
3. Suitable mill site
4. Ample water supply
5. Available tailings disposal area
6. Distance from smelter
7. Mining and milling costs

A lead-silver ore (Fig. 9-8) contains 14.2 ounces of silver per ton and 6.5 percent lead; the known ore reserves (of this grade) are 500,000 tons, sufficient to mill 300 tons per day for a period of 5 years. The mill site and tailings disposal area are satisfactory, and the water supply exceeds requirements, but 6 miles of power line must be built, and the mill site is 30 miles from the smelter.

Estimated capital cost of mill

300 tons × \$7,000	\$2,100,000
Add power line—6 miles at \$2,500*	15,000
Total	\$2,115,000

*Estimated cost/mile

Ship ore to smelter (schedule, Chapter 10)

	\$ Debit	\$ Credit
Payments		
Silver: 14.2 oz. — 1.0 = 13.2 × 95 % × \$4.15		52.04
Lead: 6.5% — 1.5 = 5.0% × 95% × \$.198		18.81
Deductions		
Treatment charge	35.00	
Haulage at 12¢/ton mile	3.60	
	38.60	70.85
Net smelter return/dry ton ore		32.25
Mining cost/ton ore		25.00
Operating profit/ton ore (less taxes)		7.25

Concentrating the ore: Mill test results coincide with those given in Figure 9-8 and are:

	Assays			% Distribution	
Product	**% Weight**	**Oz. Ag**	**% Pb**	**Ag**	**Pb**
Mill feed	100.00	14.20	6.50	100.00	100.00
Lead concentrate	8.35	150.80	64.70	88.7	83.1
Tailing	91.65	0.85	0.81		

Ship lead concentrate to smelter (schedule, Chapter 10)

	\$ Debit	\$ Credit
Payments		
Silver: 150.8 oz. — 1 × 95% × \$4.15		590.58
Lead: 64.7 — 1.5 × 95% × \$.198		237.76
Deductions		
Base charge	35.00	
Haulage at 10% H_2O 25¢/ton mile	7.50	
	42.50	828.34
Net smelter return/dry ton concentrate		785.84
Net smelter return/dry ton ore = 785.84 × 0.0835		65.62

Predicted upon known ore reserves, the life of the milling operation is 5 years. The capital investment in the mill is \$2,100,000, and this amount, in addition to a reasonable interest, must be amortized over the 5-year period.

Capital investment	\$2,115,000
Interest for 5 years compounded at 8%	992,628
Total	\$3,107,628

Amortization—$3,107,628/500,000 tons (ore reserve) = $6.22 per ton of ore. Thus, $6.22 must be assessed against every ton of ore milled.

	$ Debit	$ Credit
Payments		
Net smelter return from lead concentrate		65.62
Mining cost	25.00	
Milling cost	4.00	
Amortization of mill	6.22	
Total	35.22	65.62
Operating profit (less taxes)		30.40
Comparative returns from ore and concentrate:		
Operating profit		Per ton ore
Milling the ore—concentrate to smelter		30.40
Shipping ore direct to smelter		7.25
Estimated gain from milling the ore		$23.15

The operating profit resulting from milling the ore is 4.1 times that of shipping the ore direct to a smelter; there is no question of the advantages of building a mill.

In this instance, however, there is a profit in either, always assuming that the smelter could, and would, take 300 tons of ore daily.

Problem 2. To build a mill or to further develop the mine.—A pyritic gold ore, in which the gold occurs as sulfides and tellurides, may be beneficiated by fine grinding and flotation. Ore reserves approximate 100,000 tons. Mining cost is fairly high because ore occurs in narrow veins. Good mill sites and tailings disposal areas are adjacent to the mine; a power line crosses the property, as does a large creek. A smelter is 20 miles away. The mine is developed and equipped.

The ore contains 0.4 oz. gold per ton, and no other valuable constituents. It could not be shipped to the smelter as the following will indicate:

Ore shipped to smelter

	$ Debit	$ Credit
Payments		
0.4 oz. Au — .02 × 92.5% @ $177		62.22
Deductions		
Treatment charge	35.00	
Haulage at 12¢/ton mile	2.40	
	37.40	62.22
Net smelter return/dry ton ore		24.82

But the mining cost is $35 per ton, and shipping ore to the smelter could cause a loss of 35.00 — 24.82 = $10.18 per ton of ore.

Concentration testing of representative ore samples gave these products and recoveries:

	Assays			% Distribution	
Product	% Weight	Oz. Au	% Fe	Au	Fe
Ore	100.0	0.40	4.7	100.0	100.0
Concentrate	10.0	3.64	36.2	91.0	77.0
Tailing	90.0	0.04	1.2	9.0	23.0

The owners do not desire a mill having a capacity of less than 100 tons daily; a mill that size would have an estimated life of only 3 years, as ore reserves are only 100,000 tons. The owners are confident that ore reserves can be increased.

Capital cost	
100 tons daily at $7,000	$700,000
Interest compounded at 8%	181,798
Total	$881,798

Shipping concentrate to smelter

	$ Debit	$ Credit
Payments		
Gold: 3.64 — .02 × 92.5% @ $177		592.68
Deductions		
Treatment charge	35.00	
Haulage	3.40	
	38.40	592.68
Net smelter return/dry ton concentrate		554.28
Net smelter return/dry ton ore (554.28 × .10)		55.43

Amortization per ton of ore = \$881,798/100,000 = \$8.82.

	Per dry ton ore	
	\$ Debit	\$ Credit
Net smelter return		55.43
Mining cost	35.00	
Milling cost	5.00	
Amortization of mill	8.82	
Total	48.82	55.43
Operating profit		6.61

This particular ore, which cannot be shipped directly to the smelter profitably, can form the basis for a profitable operation with investment in a small mill. It must be emphasized, however, that every factor in the above calculation must be carefully verified before an investment is made.

ADDITIONS AND EXTENSIONS TO MILLING PLANTS

For existing concentration plants, it often happens that addition of another grinding unit is desired, because increased ore reserves favor a greater tonnage rate; or another thickener may permit recovery of lost values. For many milling operations, management will not authorize the capital investment for the changes or additions unless the entire capital cost can be returned (amortized) in a 2-year period, from the increased profits resulting therefrom.

Consider this situation: A concentrating plant is treating 200 tons daily; the ball mill feed is minus 1 inch. The installation of a rod mill, which will take the minus 1-inch feed and deliver to the ball mill a minus ¼-inch product, increases the mill tonnage rate by 50 tons daily. Flotation cells, thickeners, filters, and the like, have ample capacity for additional tonnage, and no additional labor is required. Installed cost of rod mill, motor, and connections is \$40,000. Additional operating costs are 10.5¢/ton for power and 8.5¢/ton rod and liner consumption, a total of 19¢/ton. Present milling cost is \$5/ton ore.

Capital cost	\$40,000
Interest 2 years at 8% compounded	6,656
	\$46,656

In 2 years, 160,000 tons of ore will have been milled (at 250 tons daily), and the amortization is \$46,656/160,000 = \$0.2916/ton.

Milling cost	\$ per day
200 tons at \$5	\$1,000.00
Amortization—250 tons at 0.2916	72.90
Additional cost—250 tons at 0.19	47.50
250 tons at 4.48	\$1,120.40

The net smelter return per ton of ore does not change, and we have:

	Daily tonnage rate	
	200	250
Net smelter return per ton ore	12.00	12.00
Less milling cost per ton ore	5.00	4.48
	7.00	7.52

Therefore, the operating profit has increased by \$0.52 per ton of ore.

Then 160,000 tons (2-year total) × \$0.52 = \$83,200 additional returns.

CHAPTER 10—BUSINESS ECONOMICS AND MINERAL MARKETS

By FRANK H. KELLY

INTRODUCTION

The Gross National Product (GNP) of a nation is a single total figure based on the current market price of all final goods and services produced by that nation's economy over a certain period of time, usually a year. This frequently quoted figure is used to provide some idea of that nation's economic performance when compared to other time periods or when compared to the overall performance of other economies.

THE STATISTICAL ABSTRACT OF THE UNITED STATES for 1972 indicated that GNP originating in the American mining industry showed a rising trend between 1950 and 1970. Although in 1970 the total contribution in current dollars of the mining industry was lower than that of other industries, the national significance of that contribution must be considered in the special role of mining activity as fundamental and necessary to the growth and capability of other industrial segments. Those who participate in the process of finding, developing, and processing mineral materials have a special role not only in their own area of interest but also in making a contribution that is basic to other industries.

Within the procedure used in relationship to GNP is another term—National Income—which also is of paramount significance. National income is a figure designating the total of all wages, rent, interest, and profit paid to the suppliers of the various productive resources utilized in providing goods and services.

Figures provided in the "Survey of Current Business" for May 1974 combined those for mining and construction to constitute one industry division among eleven designated industry divisions. These figures demonstrated again that the trend in national income, for 1972 through the fourth quarter of 1973, was upward in all divisions. Numerical increases in certain of the divisions, however, were not as great as those presented for mining and construction. Here again, the continued role of the mineral industries as a source of payments to other segments of the economy makes us realize that continued mineral production is vital to the development of the other specified industrial divisions. (Fig. 10-1).

Therefore, the importance of mineral activity as a direct contributor to both Gross National Product and National Income can be clearly discerned from available national statistics. The importance of the minerals industry as an indirect contributor to national figures relating to the development and progress of other industries must be clearly realized.

The United States Government first undertook a census of the nation's mineral industries in 1840 and continued the statistical determination at ten-year intervals through 1940. Subsequently, mineral industries census figures were compiled for designated years. Legislation in 1964 required that an economic census be taken in 1964, 1968, and then every fifth year thereafter covering the years ending in 2 and 7.

Economic census data are invaluable for business evaluation of potential markets, for economic forecasting, for the location of plants and warehouses, and for analysis of sales performance. Received and correlated census information is most important also in the determination of Gross National Product and National Income, the derivation of indexes relating to price and productivity, and in assistance to state and local governments in comprehending economic changes and developments within their jurisdictions. (Fig. 10-2).

The forms for reporting mineral industries data are prepared by the Bureau of the Census specifically to cover certain definite mineral-related activities. For example, the forms submitted for obtaining 1972 information on copper, lead, zinc, gold, and silver ores required information about the number of employees, physical location of the mineral establishment, payrolls and labor costs, man-hours of production, mineral rights and geological expenditures, capital expenditures, mineral development and exploration expenditures, and many other types of similar information. The various questionnaires relating to mining activity were prepared after consultation with numerous governmental agencies, various business organizations, mining trade associations, and individuals actually engaged in mineral-related activities.

The basic mailing lists were compiled from reports submitted to the Social Security Administration and the Internal Revenue Service. Various decisions led to the exemption of about 8,000 small mining firms (one to four employees) from filing these required census forms in the 1972 census. Title 13, United States Code, requires that the appropriate form be completed and returned by the operator of the covered firm to the Bureau of the Census. The confidentiality of such information is protected; copies retained in the files of the reporting firm or person are immune from legal action.

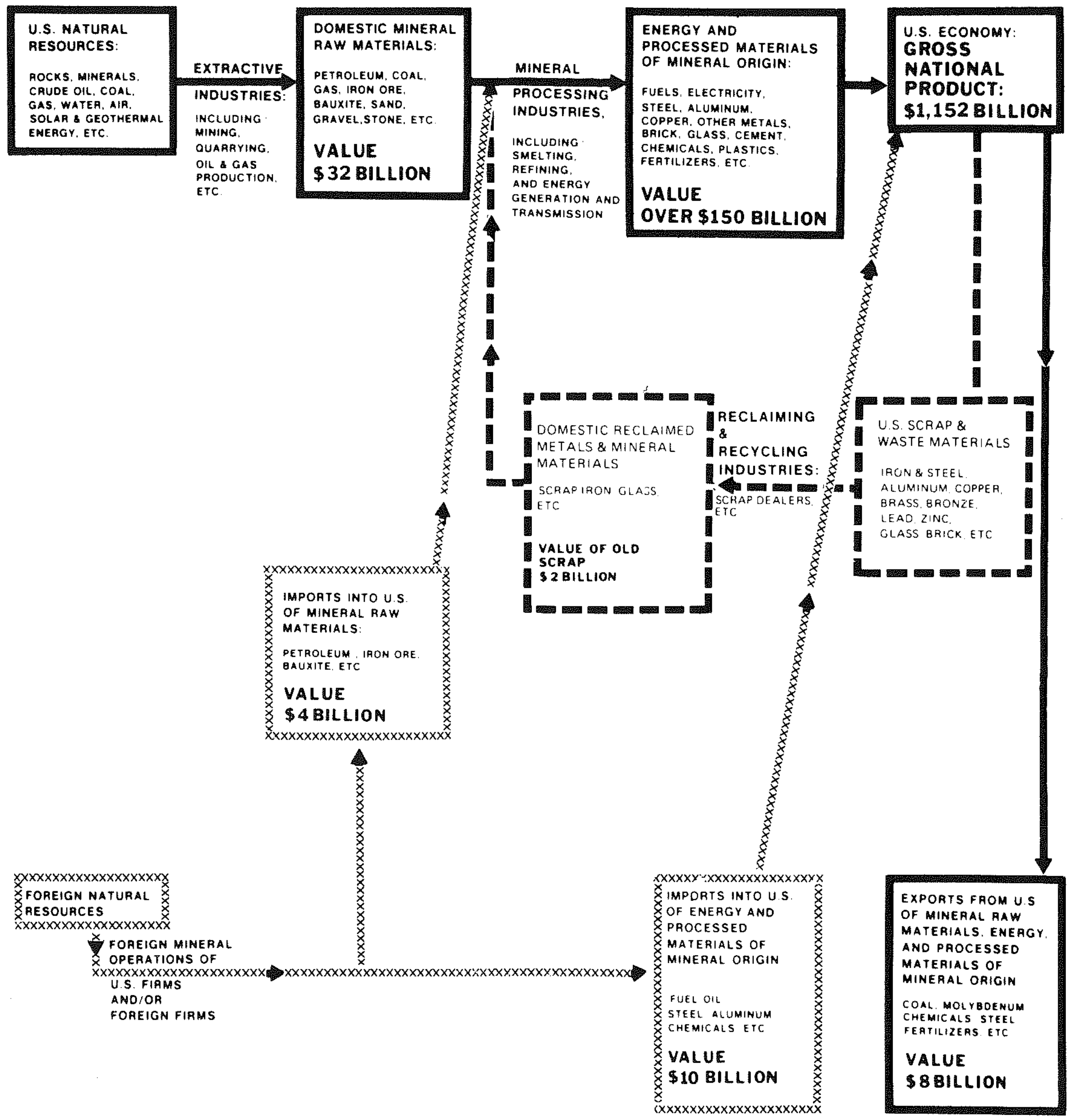


FIGURE 10-1.—The role of minerals in the U.S. economy (U.S. Secretary of the Interior, 1973, p. 26. Reprinted with permission.)

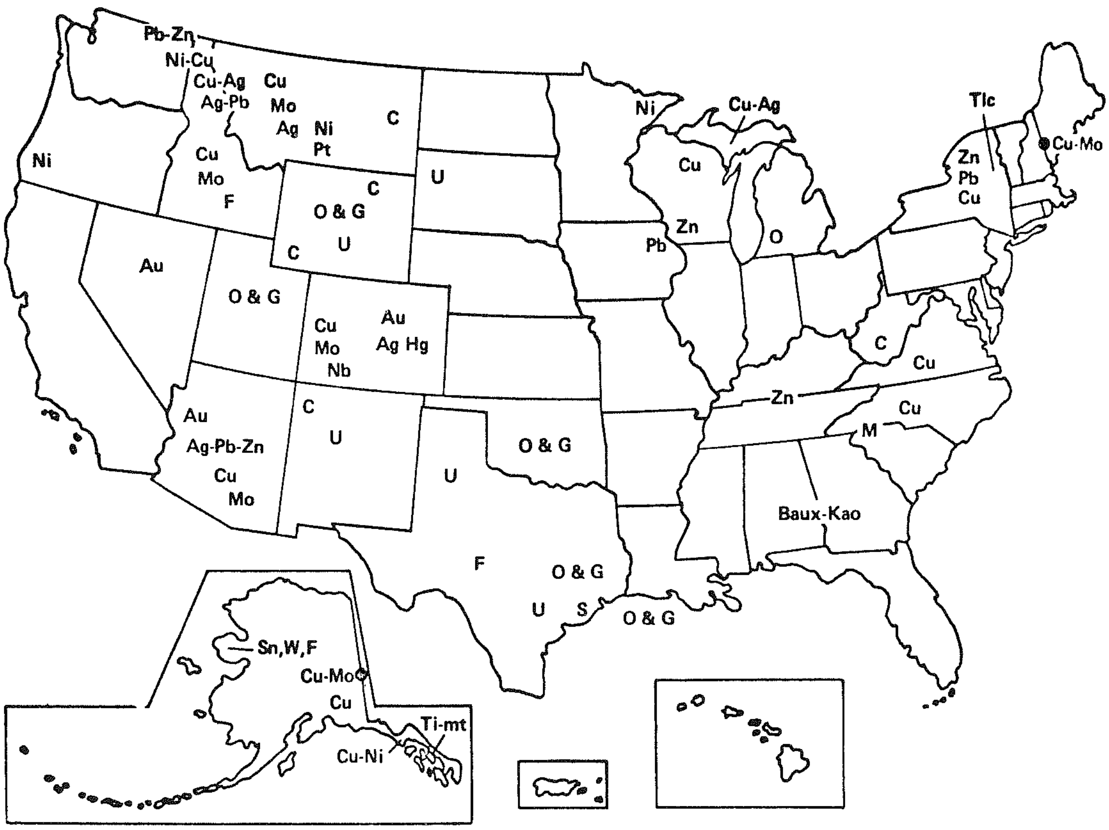
BUSINESS OWNERSHIP

Figures for 1972 indicate that individual ownership is utilized in the United States much more than either the partnership or the corporation as a form of business ownership. Following a similar pattern, in 1972 the number of individually owned businesses in mining-related activity exceeded either partnerships or corporations grouped singly or collectively. This reference is only to the **number** of firms using these forms of business ownership, not to the dollar value of their production.

Recent figures show that of 59,000 individually owned mining ventures, 53,000 were reported to be in the "under $50,000 category while 3,000 were in the $50,000-$99,000 bracket and the remaining 3,000 exceeded $100,000". (Statistical Abstract of the United States, 1972, table 749, p. 471). The same table showed 10,000 partnerships in the first range, 1,000 in the second grouping, and fewer than 500 in the third. Of the 14,000 active corporations, 12,000 were in the lowest bracket and 1,000 were reported in each of the others.

EMPLOYMENT

Without references to the form of business ownership, the Bureau of Labor Statistics of the United States Department of Labor has compiled historical data on the number of persons employed



SYMBOL	COMMODITY	SYMBOL	COMMODITY
Ag	SILVER	Nb	NIOBIUM (COLUMBIUM)
Au	GOLD	Ni	NICKEL
Baux	BAUXITE (ALUMINUM)	O	OIL
C	COAL	Pb	LEAD
Cu	COPPER	Pt	PLATINUM
F	FLUORINE	S	SULFUR
G	NATURAL GAS	Sn	TIN
Hg	MERCURY	Ti-mt	TITANIFEROUS MAGNETITE
Kao	KAOLIN	Tlc	TALC
M	MONAZITE	U	URANIUM
Mo	MOLYBDENUM	W	TUNGSTEN
		Zn	ZINC

FIGURE 10-2.—Areas of principal domestic mineral exploration by industry, 1972. (U.S. Secretary of the Interior, 1973, p. II-2. Reprinted with permission.)

in the United States in mining activity as a goods-producing industrial division. Thus, 1,133,000 persons were so employed in 1919, and a year later that figure had risen to 1,239,000. Except for 1937 when 1,015,000 were indicated as working in mining activity, the figure never again exceeded one million; it reached a low point of fewer than 600,000 early in 1973. By February 1974, there were 658,000 persons so employed.

BUSINESS FORMATIONS AND FAILURES

From 1950 to 1971 new business incorporations in the United States increased from 93,000 to 288,000 except for a slight dip between 1969 and 1970. The number of business failures per year reached a maximum of 15,445 in 1960, dropped to 9,154 in 1969, and rose to 10,748 and 10,326 in 1970 and 1971, respectively. The failures included firms that were discontinued because of petition in bankruptcy, those that voluntarily withdrew from business with a known loss to creditors, other firms involved in receivership and reorganization, and those businesses making out-of-court compromises with creditors. Additional reasons for discontinuances are also included in those failure figures.

The "Survey of Current Business" for May 1974 combined manufacturing and mining; it indicated 1,576 failures in 1972 among the total of 9,566 industrial and commercial failures in the United States. In 1973, the figures were 1,419 and 9,345, respectively. Moreover, current liabilities of all failed businesses in these two years (1972 and 1973) totaled $2,000,244,000 and $2,298,606,000, respectively, of which manufacturing and mining, again in combination, accounted for $766,991,000 in 1972, and $797,490,000 in 1973. It was evident that although the greatest number of business failures in each of these two years was in the retail-trade category, the amount of total current liabilities involved in retail trade in 1972 and 1973 was below that of mining and manufacturing in each of these years.

In a pamphlet published in 1967 by Dun and Bradstreet, Inc., various causes of business failures in 1966 were detailed, and the percentage distribution was allocated among manufacturers, wholesalers, retailers, construction, and commercial service. The greatest underlying causes of failures in these activities were designated as inexperience in the line, lack of managerial experience, not well-rounded experience in sales, finance, purchasing, and production, and also incompetence. These causes accounted for 93.4% of the failures in 1966. Listed as further underlying causes were neglect, fraud, disaster, and reason unknown.

In an August 1974 newspaper column, Sylvia Porter, nationally syndicated columnist on business and financial matters, indicated that the "odds against your surviving even five years will be close to six out of ten—the highest odds against you since 1966 . . . ." She reported that the number of failures was "up 6.4% in the first five months of 1974 over the same period of 1973 . . . the number of actual business failures reported to Dun and Bradstreet, Inc., by the time 1974 ends will have crossed 10,000" (Porter, 1974). Emphasized in this article is the general importance of managerial incompetence, ineptitude, and inexperience in nine of ten cases of business failure.

The United States Small Business Administration (SBA) indicated in a 1973 publication describing its functions, programs, and activities that "Most businesses fail for lack of good management. For this reason SBA offers a diversified program of management and technical assistance to strengthen small firms and to improve their operations" (U.S. Small Business Administration, 1974, p. 25). Indeed, the SBA indicates that "It is estimated that 9 out of 10 business failures are due to managerial deficiencies" (U.S. Small Business Administration, 1972, p. 1).

MANAGEMENT ASSISTANCE

The Small Business Administration (SBA) was created by Congress in 1953 with the specified intent, as stated in the Small Business Act, " . . . that the Government should aid, counsel, assist, and protect insofar as is possible, the interests of small business concerns in order to preserve free competitive enterprise . . . to maintain and strengthen the overall economy of the Nation."

Nineteen of twenty business firms in the United States would be categorized as small business. Altogether, small businesses provide approximately 35,000,000 jobs and contribute more than $475,000,000,000 annually to GNP.

SBA has available numerous publications relating to various aspects of organizing and managing a business.

Examples of publications available without charge are:

"Small Marketers Aid No. 71 . . . Checklist for going into business"
"Insurance Checklist for Small Business"
"How to Analyze Your Own Business"
"The Metric System and Small Business"
"Designing Small Plants for Economy and Flexibility"
"The ABC's of Borrowing"
"Is Your Cash Supply Adequate?"
"Delegating Work and Responsibility"
"What Is the Best Selling Price?"
"Keep Pointed Toward Profit"
"Records Retention: Normal and Disaster"
"The Equipment Replacement Decision"
"Reducing Air Pollution in Industry"
"Building Strong Relations With Your Bank"
"Analyze Your Records to Reduce Costs"
"Getting the Facts for Income Tax Reporting"

Examples of for-sale booklets in the Small Business Management Series are:

"Handbook of Small Business Finance"
"Ratio Analysis for Small Business"
"Insurance and Risk Management for Small Business"
"Guides for Profit Planning"

Another series of publications available at a charge are categorized within the Small Business Research Series. Examples include:

"The First Two Years: Problems of Small Firm Growth and Survival"
"Personality and Success: An Evaluation of Personal Characteristics of Successful Small Business Managers"
"Managing for Profits"
"Strengthening Small Business Management"

The Small Business Administration has about 85 field offices throughout the United States. Representatives are most willing to discuss the agency's functions and programs and to render assistance to the small businessman in dealing with management problems. Thus, the SBA provides courses, conferences, workshops, clinics, and direct management counseling. Staff professionals and persons experienced in the many facets of business operation are a 'talent pool' from which analyses of general and specific problems may be provided in conjunction with suggestions and plans to remedy existing deficiencies. Assisting the SBA are members of SCORE (Service Corps of Retired Executives) and ACE (Active Corps of Executives). Both groups consist of businessmen possessing experience, knowledge, and familiarity with the problems faced by a businessman in small but vital businesses.

LOAN ASSISTANCE

The SBA requires that private financing be sought first before a loan application is made to the agency, as its direct-loan funds have been seriously depleted over the years. The SBA may now guarantee as much as 90% of a bank loan to a small business but not to exceed a maximum guarantee of $350,000. For mining ventures, the loan guarantee is for development of an identifiable ore body; the funds are not available for SBA guarantee if their use is intended for exploration and prospecting.

Copies of two of SBA's forms required for mining ventures are reproduced at the end of this chapter as Figure 10-3 and 10-4. Form 4B for a production loan must be completed, submitted, and approved first. Form 4, Application for Loan, will then be received and processed. Among the legal limitations on SBA participation is a prohibition against loans for speculation in any kind of property. As of August 1974, approved SBA loans in the mining classification throughout the United States totaled $72,773,472.28, and of this amount the SBA share was $59,973,075.29. As of the same date the SBA had approved 828 loans nationally to small businesses in the same classification.

The Standard Industrial Classification (SIC) represents a division of all economic activity according to major industry, such as mining, which includes as subsections: metal mining, anthracite mining, bituminous coal and lignite mining, oil and gas extraction, and mining and quarrying of nonmetallic minerals except fuels. The SIC is used by federal government agencies engaged in classification of various firms and is now used by state and local governments also. Mining is assigned numbers 1011 through 1499, and the subsections listed are 10, 11, 12, 13, and 14, respectively. There is an additional breakdown within each of these subsections; for example, 1044 relates to silver ores and 1477 to sulfur. A breakdown of loan approvals listed by SIC and exceeding $1,000,000 in each category follows:

TABLE 10-1.—SBA loan approvals by SIC designation.

SIC		No. of loans	Total amount	SBA share
1011	(Iron ores)	13	$ 1,077,000	$ 942,325
1021	(Copper ores)	9	1,061,500	965,500
1211	(Bituminous coal and lignite)	190	17,367,875	14,457,493
1213	(Bituminous coal and lignite mining services)	17	2,248,032	1,966,436
1411	(Dimension stone)	20	1,414,500	1,235,550
1421	(Undisclosed)	116	10,646,400	8,370,971
1422	(Crushed and broken limestone)	29	4,777,000	3,490,350
1429	(Crushed and broken stone)	18	2,403,700	2,147,300
1441	(Undisclosed)	202	11,402,951	9,493,673
1442	(Construction sand and gravel)	85	10,367,970	8,320,363

Loans for other purposes are also possible through SBA; for example, loans to eligible small businesses adversely affected by a natural disaster. Further information regarding loans for such other purposes may be obtained from the SBA.

METHODS OF MARKETING

Marketing procedures established over the course of time have been devised to solve the problems specific to each industry. When most goods were sold on a local basis, marketing was simple; the development of mass consumption required a marketing structure both extensive and efficient enough to handle the demands of a vastly expanded population.

Selling a product is the basic activity with which marketing is involved. Sometimes only legal transfer of ownership applies, and the physical commodity is represented by a sample only rather than by the entire lot. Generally, the activities associated with marketing may involve assembling a product, standardizing or classifying the goods according to accepted designations, transporting and storing a product, and risk taking.

Understanding the methods now employed to market mineral resources involves knowledge of the nature of the commodity, a recognition of the fact that other materials may be associated with it, and a familiarity with economic considerations that influence price. Variations in the quality of minerals makes a satisfactory grading system most difficult to establish. Many minerals are sold on the basis of chemical or physical analysis, and different users may have quite dissimilar specifications. The role of the national government in the marketing of mineral resources must also be considered.

Marketing of natural resources is somewhat simplified because of the relationship between suppliers of raw materials and the firms that use these raw materials. It may be necessary, however, for small independent producers to deal with large integrated organizations. Independent middlemen, active in the marketing of many other commodities, play little part in the marketing of mineral products. A table of the buying and selling groups for nonferrous mineral products follows.

TABLE 10-2.—Buying and selling groups for nonferrous mineral products.

Form in which sold	Buyers	Sellers
Crude ore	Ore dealers Custom mills Custom smelters Consumers	Miners Ore dealers
Concentrates	Custom smelters Consumers Ore dealers	Miners Custom mills Ore dealers
Bullion, blister	Refiners	Custom smelters Dealers
Scrap	Dealers Custom smelters Refiners	Dealers Manufacturers Junk collectors
Refined metal	Consumers Dealers Speculators	Refiners Dealers Speculators

(Robie, E. H. (ed.), 1959, p. 296. Reprinted with permission of AIME.)

THE PRICING MECHANISM

The determination of the price of an item available for sale in a particular market is dependent upon such usual costs as those for materials, labor, power, interest, transportation, and taxes. The necessity of overcoming rising costs is particularly strong in the mineral industries.

The mechanics of the pricing of mineral commodities involves additional considerations such as (1) the numerous varied grades of commodities and their specialized uses, (2) quantity purchases, which may involve prices different from those regarded as established, (3) the recognized unit of measurement, (4) the availability of synthetic products, and (5) transactions on an organized commodity or metal exchange.

The following table categorizes various nonmetallic mineral commodities according to their physical and chemical properties and demonstrates further the influence affecting the pricing mechanism.

TABLE 10-3.—Relative importance of physical and chemical properties.

Physical properties paramount	Both physical and chemical properties important	Chemical composition paramount
Abrasives	Barite	Agricultural limestone
Adsorbents	Clays	Bauxite
Asbestos	Feldspar	Borates
Bentonite	Glass sand	Fertilizer materials (phosphate rock, potash, and nitrates)
Building stone and slate	Graphite	Fluorspar
Clays	Kaolin (some uses)	Gypsum
Crushed stone	Limestone and lime	Limestone and lime (chemical use)
Diatomite	Portland cement raw materials	Lithium minerals
Fuller's earth	Pyrophyllite	Magnesite
Garnet	Talc	Pyrite
Kaolin (some uses)	Wollastonite	Salt
Mica		Sodium compounds
Mineral fillers		Sulfur
Perlite		Titanium minerals
Pumice		Zircon
Quartz crystals		
Sand and gravel		
Talc		
Vermiculite		

(Robie, E. H. (ed.), 1959, p. 300. Reprinted with permission of AIME.)

Most ores are bulky, a combination of metals and gangue minerals. Hence, the process of marketing is more complicated if it is necessary to transport this bulky material over a considerable distance. Consequently, the first stages of benefication are generally undertaken as near the mine as possible.

A market is frequently defined in economics as the condition in which buyers and sellers communicate with each other in order to effect an exchange.

Prices of certain nonferrous ores are based on delivery at a particular location and on a designated metal content. Direct purchase from miners or dealers, and direct individual negotiation between buyers and sellers are characteristic. Vanadium, tungsten, and molybdenum are representative of this group.

Copper, lead, tin, and zinc are another grouping. Their price volatility results from acute competition. Alternating periods of oversupply and then shortage are a distinctive feature of the market for these metals. The reaction of custom smelters to such price variations is demonstrated by the action of these purchasers in increasing or decreasing their price depending upon estimates of the market strength for these commodities. Established specifications for the four metals are generally known and accepted.

Other metals, for example nickel and aluminum, require larger investment in the processing plant than in the mine. As a group, these metals are produced in vertically integrated operations, which encompass all steps in a process from the mine to the ultimate product. Basically, the price structure is stable, and commodities such as these are not traded on an organized exchange.

Antimony, bismuth, cadmium, and cobalt are examples of yet another price group. Most are byproducts of the processing of other metals such as copper, lead, and zinc. The market involves infrequent price changes, the users of these minor metals seeking small wholesale lots.

Most of the gold, which has approximately 400 American producers, and silver, which has about 500, is mined and recovered as byproduct of the refining of other metals. Quality is stated in fineness (purity), 999 (per 1000) fine being a representative figure. The platinum group metals (platinum, iridium, palladium, rhodium, and ruthenium) involve a sensitive market in which imports meet American requirements. There is not a well-defined price but rather trade occurs within a bid-and-asked range. The metals in this group are sold by the troy ounce.

It is recommended that a careful study of existing and probable future markets for industrial minerals be undertaken before making an appreciable investment. The employment of qualified consulting engineers or survey firms may be of significant value in guiding ultimate investment decisions. A compilation of such firms and individuals is available in Engineering and Mining Journal 1973-1974 International Directory of Mining and Mineral Processing Operations, section 3.

Some commodities are extensively supplied from foreign sources, for example, asbestos, beryl, chromium, cobalt, diamonds, (sheet) mica, rutile, and tantalum. Despite a tendency by American mining companies to spend increasing percentages of available investment funds in domestic enterprise, the United States is faced with increasing dependence on foreign raw materials sources.

ORGANIZED EXCHANGES

Centers for establishing accepted single impersonal prices for various commodities that could otherwise conceivably involve thousands of individual transactions are the national exchanges in diverse locations throughout the United States. The established price applies to both buyers and sellers at a given time only, and price quotations are based upon standardized specifications for weight, grade, quantity, and durability. These exchanges may deal in such varied items as butter, cocoa, coffee, cotton, grains, rubber, sugar, wool, and certain minerals. They establish their own commissions and margin requirements, which are really provisions to compel completion of contracts.

Commodity Exchange, Inc. (Comex), New York, provides the facilities, the mechanism, and the rules and regulations whereby those concerned with the purchase and sale of silver, copper, lead, mercury, rubber, tin, and zinc for future deliveries can transact their business in an orderly fashion. Only those persons who hold membership on Comex can actually execute an order, although membership is unnecessary to trade through Comex. Commissions paid to Comex members for handling contracts are open to competition and are not fixed by the exchange. Comex does place limitations on the range within which copper and silver futures prices can vary in a single trading day.

This exchange handled futures contracts for 11 billion troy ounces of silver and 7 trillion tons of copper in 1973. Between 1969 and 1973, silver futures annually averaged 7.8 billion troy ounces. This volume established Comex as the world's paramount futures market in silver and one of the two leading futures markets in copper.

Each silver contract (a 10,000-ounce lot) calls for the delivery of refined silver in standard bars at some specified future month at the price established on Comex through a reported official transaction. Actual deliveries of standard (999 fine) silver must be made at a Comex approved and licensed warehouse (probably a bank vault that meets Comex's standards for safety and protection against theft). As of 1972, all these warehouses were located in New York City.

Each copper contract is a unit of 12.5 short tons and specificies delivery of the 25,000 lb. (2% more or less) of Lake, fire-refined, or electrolytic copper in ingots or other standard refinery shapes. Warehouses approved by Comex for the delivery of copper are situated at various places in the United States. Incidentally, one of the problems experienced in the new copper futures market of the International Monetary Market (IMM) of the Chicago Mercantile Exchange has been the lack of warehouse facilities. Ten warehouse locations in addition to those available in Chicago and St. Louis were being sought by this market.

Prices established on Comex are printed in financial and trade publications the world over, thus reflecting the significance of its transactions as a price gauge.

Publications describing the complexities of silver and copper futures activities on Comex may be obtained by writing to Commodity Exchange, Inc., 81 Broad Street, New York 10004.

The London Metal Exchange historically traces back to the time when the flow of different metals to England's shores resulted from that country's international position not only as the world's financial center but also as a major receiver and distributor of numerous commodities. This exchange has its recognized warehouses in various English cities and provides the facilities for varieties of trading procedures in silver, copper, lead, tin, and zinc. During the short time the exchange is open each day for price bidding there is a five-minute-per-metal limitation.

The New York Mercantile Exchange provides market facilities for price determination of metals such as palladium and platinum in units of 100 troy ounces.

Price Quotations relating to metals, ores, and concentrates involve varied significant features, for example the price at a given location; the myriad number of qualities, shapes, and grades; the use of long or short tons, flasks, kilos, or lots as the unit of measurement; the inclusion or exclusion of a certain chemical, the shipping stipulations such as f.o.b. or c.i.f., and the applicable import duty.

Reproduced to show this tremendous price variation are pages 60, 64, 66, and 70 of the June 1974 issue of "Engineering and Mining Journal" (reprinted by permission). This monthly magazine is an excellent source for price and other information relating to the mineral industries in the United States and worldwide. (These particular pages are presented at the end of this chapter as Figure 10-5.)

"Metals Week", also a McGraw-Hill publication, is frequently used as the source for price determination and settlements involved in smelter schedules. This weekly publication is recognized also as authoritative and contains both weekly and daily prices for designated commodities, as well as reports of developments affecting these commodities. Sample pages from the July 29, 1974, issue are also included as Figure 10-6 (reprinted by permission).

It is impossible in this publication to explain every listed term or designation. The reproduced pages from "Engineering and Mining Journal" and "Metals Week" provide an excellent and valuable compilation accentuating completeness, accuracy, and variation.

CUSTOM SMELTING

The impact of changing — and rising — costs experienced in recent years throughout all sectors of the American economy has been understandably reflected in the hesitancy of custom smelters to publish their rates and charges. Uncertainty about future costs makes it unreasonable under existing economic conditions to expect such schedules to be valid for more than a relatively short period of time. This situation is, of course, covered by the inclusion of the expression "subject to change without notice" in the smelter schedule.

Should a small-mine operator be interested in developing a specific property, it is recommended that he give active and continuing consideration to such factors as the expected quantity of ore from the property, the date the operation may commence, the origin of production, and the location of the closest shipping point. A complete chemical analysis together with a representative sample should be submitted to a custom smelter for its terms before the operator incurs additional development expense. After the smelter terms are received, he should be in a stronger position to assess the probable return for his particular mineral product.

The following statement, made several years ago, bears repetition, "Many small mine owners, on the other hand, could get more favorable terms if they would pay more attention to the making of their ore-selling contract. Although some fail to realize it, this may be as big a factor in the success of their enterprise as the intelligent development of the mine or the efficient extraction of the ore." (Spear and Wormser, 1925, p. 587.)

The shipment of crude ore or concentrate to a custom smelter provides a means whereby a person engaged in a small mining operation may receive some payment toward his expenses as he proceeds in his mining activity. Although smelter ore-buying contracts may be complex, they are not inexplicable.

The smelter, which is expensive to establish, may need a mixture of ores from a variety of mines in order to provide the ingredients essential for a satisfactory smelter charge. Moreover, the smelter must have adequate supplies of ore to assure a continuing and uniform level of operation, because the smelter should perform at full capacity to provide for maximum distribution of its overhead or fixed costs. A smelter must receive enough return to smelt ore and concentrate, to refine the metal produced, and to deliver the final product to an established market.

Each custom smelter is different, and each must consider the proposed product's suitability to its particular process as well as the amount of metal recovery, its costs of supplies, and its distance from refineries or markets.

Generally speaking, a smelter schedule details those ore constituents for which payment will be made and designates the deductions to compensate for the loss of metal in the smelting process. Also included are the specific sources upon which initial price would be quoted. Additionally, the schedule details the deductions the smelter may make for demurrage, for treatment charges, for the presence of totally unwanted constituents, for excessive moisture, for charges to cover required pollution-control expenses, and for import duties, taxes, and surcharges. Changes in the base labor rate and the cost of freight to market, as adjusted to coincide with upward or downward major variations in these rate provisions, may also be specified. Other provisions may include the definition of quotations and settlement as well as requirements relating to mode of transport by rail car. All of these specification and requirements will vary, depending upon the needs and processes of the specific smelter.

Schedule provisions denoting unusual situations may prevail. For example, White Pine Copper Company, White Pine, Michigan, allows for the effect of winter freezing by stipulating that if the buyer (smelter) undergoes unusual demurrage or unloading expenses in that particular season because of the irregularity of shipments or the frozen condition of the ore in the rail cars, the buyer can suspend shipments pending restoration of normal shipping conditions. Moreover, during that same period of November 1 to April 1, concentrates are to be shipped in insulated cars if these are available. Additional escalating charges for uncontrolled increase of moisture during those months are also specified.

The Anaconda Reduction Department, Anaconda, Montana, division of The Anaconda Company, purchases siliceous ores (but no tailings) based upon a silica content of 70% or more after allowing for deductions for both iron and alumina. Payments for contained copper, silver, gold, and silica are detailed, based on specified "Metals Week" prices. The schedule, which details pertinent provisions, contains the stipulation that it is subject to change without notice.

Company procedure to determine the acceptability of crude material necessitates the shipment of a representative sample to the Reduction Department. If, after analysis, the material is judged to be acceptable, the Department authorizes shipment of a trial lot, which is subject to additional analysis. If the material again proves acceptable, the Reduction Department prepares a quota arrangement governing shipments to the smelter.

The Department advises that compliance with this procedure be undertaken as soon as possible in the development of the property, because conditions other than the chemical and metallic analysis of the material could affect the ability of the smelter to continue receiving that material. Shipments to the smelter should be made in flat-bottom gondola cars or end-dump trucks, but the shipper must realize that these shipments will not be accepted unless prior arrangements have been made between smelter and shipper. The Department reserves the right upon its written notice to the shipper to restrict or stop any or all shipments.

The names and addresses of some custom smelting companies are listed below:

American Smelting and Refining Co.
Manager, Ore Department
120 Broadway
New York, NY 10005

Bunker Hill Company, The
(A subsidiary of Gulf Resources and Chemical Corp.)
301 The Old National Bank Building
Spokane, WA 99201
Mine Office: P.O. Box 29
Kellogg, ID 83837

Cominco, Ltd.
Consolidated Mining and Smelting Co. of Canada
200 Granville Square
Vancouver, 2, B.C., Canada

Phelps Dodge Refining Corporation
300 Park Avenue
New York, NY 10022

Inspiration Consolidated Copper Corp.
55 Madison Avenue
Morristown, NJ 07960

Amax Copper, Inc.
1270 Avenue of the Americas
New York, NY 10020

National Zinc Company, Inc.
P.O. Box 579
Bartlesville, OK 74003

Magma Copper Corp.
300 Park Avenue
New York, NY 10022

Examples of the general arrangement, terms, and specifications of schedules for both lead concentrates and copper concentrates follow, together with deriviations of smelter values for both concentrates based upon the schedule provisions. Also presented are examples of a smelter's general clauses governing all open schedules.

Some responses received in answer to requests for custom-smelter schedules indicated that material regarded as acceptable for smelting is judged on the basis of the quality of individual shipments and that the provisions of eventual payment negotiations are consequently deemed confidential.

A few firms, however, confirmed their desire to purchase for smelting. For example, Gulf Chemical and Metallurgical Company, Texas City, Texas, expressed willingness to buy tin-bearing materials, concentrates, and byproducts but would make specific quotations upon receipt of details

PURCHASE SCHEDULE Ø __________

DATE EFFECTIVE [illegible]

SHIPPER __________ ADDRESS __________

MINE __________ LOCATION __________

PRODUCT LEAD CONCENTRATES R. R. STATION __________

The following purchase terms are subject to the General Clauses shown on the back of this sheet, and are subject to change on 30 days notice. Unless shipments are begun within 30 days this quotation is automatically cancelled.

DELIVERY: F.o.b. rail cars at unloading bins of the Buyer's Plant. The rates quoted are based on shipment in open top gondola equipment. Extra unloading charges of up to $2.00 per wet ton will be assessed for product received in other equipment.

PAYMENTS

GOLD: Deduct 0.02 troy ounces per dry ton and pay for 92.5% of the remaining gold content at th daily London Final Gold Quotation, as published in Metals Week, averaged for the calendar month following date of delivery of product, less a deduction of 50¢ per troy ounce of payable gold. All purchases of gold will be subject to United States Governmental regulations pertaining to transactions in gold.

SILVER: Deduct 1.0 troy ounces per dry ton and pay for 95 % of the remaining silver content at the Handy and Harman New York Quotation for refined silver averaged for the calendar month following date of delivery of product, less a deduction of 6.0 ¢ per ounce.

LEAD: Deduct from the wet lead assay 1.5 units and pay for 95 % of the remaining lead at quotations for common domestic lead for delivery in New York as published in Metals Week averaged for the calendar month following date of delivery of product, less a deduction of 4.7 ¢ per pound of lead accounted for. The quantity of lead not paid for shall equal a minimum of 3.0 units per net dry ton.

COPPER: Deduct from the wet copper assay 1.3 unit and pay for 97.5 % of the remaining copper at the daily net domestic refinery quotations for electrolytic wire bars as published in the Metals Week averaged for the calendar month following date of product, less a deduction of 13.0 ¢ per pound of copper accounted for. Nothing paid for copper if less than 2.0 % by wet assay.

NO PAYMENT WILL BE MADE FOR ANY METAL OR CONTENT EXCEPT AS ABOVE SPECIFIED.

DEDUCTIONS

BASE CHARGE: $ 35.00 per net dry ton of 2,000 pounds.

LABOR: This quotation is based upon an average hourly cost of employment of $ 7.00 at Buyer's Plant. To adjust, increase or decrease Base Charge by 0.5¢ for each 1¢ per hour that the average hourly cost of employment at Plant during the calendar month prior to the date of delivery of product is greater or less than $7.00, fractions in proportion.

ARSENIC:	Allow 0.5 units free; charge for excess at $ 0.75 per unit)	FRACTIONS
ANTIMONY:	Allow 0.5 units free; charge for excess at $ 1.00 per unit)	IN
BISMUTH:	Allow .05 units free; charge for excess at $ 0.50 per lb.)	
NICKEL:	Allow .3 units free; charge for excess at $ 3.00 per unit)	PROPORTION

TAXES: See Clause 1 on reverse side of this schedule.

FREIGHT: All railroad freight and delivery charges for account of Shipper. Deduct from settlement freight and other advances made by Buyer.

FREIGHT BULLION: This schedule is based upon a published 50 ton carload freight rate on lead and copper bullion of $41.26 and $37.57 respectively.

TONNAGE: Limited to __________ tons per month.

By __________

PURCHASE SCHEDULE Ø________ ________

DATE EFFECTIVE July 1, [illegible]

SHIPPER________________ ADDRESS________________

MINE________________ LOCATION________________

PRODUCT COPPER CONCENTRAYES ________ R. R. STATION________________

The following purchase terms are subject to the General Clauses shown on the back of this sheet, and are subject to change on 30 days notice. Unless shipments are begun within 30 days this quotation is automatically cancelled.

DELIVERY: F.o.b. Rail cars at unloading bins of the Buyer at Plant. The rates quoted are based on shipment in open top gondola equipment. Extra unloading charges of up to $2.00 per wet ton will be assessed for product received in other equipment.

PAYMENTS

GOLD: Deduct 0.02 troy ounces per dry ton and pay for 92.5% of the remaining gold content at the daily London Final Gold Quotation, as published in Metals Week, averaged for the calendar month following date of delivery of product, less a deduction of 75¢ per tro ounce of payable gold. All purchases of gold will be subject to United States Governmental regulations pertaining to transactions in gold.

SILVER: Deduct 1.0 troy ounces per dry ton and pay for 95 % of the remaining silve content at the Handy and Harman New York Quotation for refined silver averaged for the calendar month following date of delivery of product, less a deduction of 6.0 ¢ per ounce.

COPPER: Deduct from the wet copper assay 1.0 unit and pay for 97.5% of the remaining copper at the daily net domestic refinery quotation for electrolytic wire bars as published in Metals Week averaged for the calendar month following date of delivery of product less a deduction of 7.6 ¢ per pound of copper accounted for. Nothing paid for copper if less than 1.0 % by wet assay.

NO PAYMENT WILL BE MADE FOR ANY METAL OR CONTENT EXCEPT AS ABOVE SPECIFIED.

DEDUCTIONS

BASE CHARGE: $ 35.00 per net dry ton of 2,000 pounds.

LABOR: This quotation is based upon an average hourly cost of employment of $ 7.00 at Buyer's Plant. To adjust, increase or decrease Base Charge by 10.0¢ for each 1¢ per hour that the average hourly cost of employment at Plant during the calendar month prior to the date of delivery of product is greater or less than $7.00 fractions in proportion.

ZINC:	Allow 5.0 units free; charge for excess at $ .30 per unit)	FRACTIONS
ARSENIC:	Allow 0.5 units free; charge for excess at $ 1.00 per unit)	
ANTIMONY:	Allow 0.2 units free; charge for excess at $ 1.50 per unit)	IN
BISMUTH:	Allow 0.05 units free; charge for excess at $ .50 per lb.)	
NICKEL:	Allow 0.3 units free; charge for excess at $ 5.00 per unit)	PROPORTION

TAXES: See Clause 1 on reverse side of this schedule.

FREIGHT: All railroad freight and delivery charges for account of Shipper. Deduct from settlement freight and other advances made by Buyer.

FREIGHT BULLION: This schedule is based upon a published 75 ton carload freight rate on lead and copper bullion of $32.31 ~~and~~ ~~---~~ ~~respectively~~.

TONNAGE: Limited to ________ tons per month except by special arrangement.

GENERAL CLAUSES GOVERNING ALL OPEN SCHEDULES

1. TAXES: All taxes or other governmental charges, national, local or municipal, now or hereafter imposed in respect to or measured by the product purchased hereunder, or the production, extraction, smelting, refining, sale, transportation, proceeds or value thereof, or of the metals derived therefrom, other than income taxes levied upon the BUYER, shall be for account of the SELLER and shall be deducted from the purchase price payable hereunder.

2. SAMPLING: Weighing, moisture and ore sampling (at which Seller or a representative may be present) as done by Buyer according to standard practice, promptly after receipt of product, will be accepted as final. The absence of Seller or a representative shall be deemed a waiver of the right in each instance. After sampling, the product may be placed in process, commingled, or otherwise disposed of by Buyer.

3. ASSAYING: As soon as available Buyer will furnish a pulp sample to Seller, or to Seller's representative or the firm handling Seller's assay work. On Seller's request Buyer will make assay comparison with Seller, or his representative by exchange of assay certificates over the counter. Comparison may be made by exchange of certificates through the mail, and in such event Buyer and Seller will mail to each other their respective assay certificates on the sixth day following date appearing on smelter pulp sample envelope, or other such date as may be agreed upon. The following splitting limits will be used for comparison of assays under either exchange method listed above:

Gold	.02 troy ounce per ton	Arsenic	0.5%
Silver	.5 troy ounce per ton	Antimony	0.2%
Lead	0.5%	Bismuth	0.02%
Copper	0.3%	Nickel	0.1%
		Zinc	0.5%

If assays of Buyer and Seller are within limits above specified, settlement assays will be determined by averaging the two results. If assay comparisons indicate differences greater than the above limits, control sample shall be submitted to umpire. Umpires shall be selected in rotation from a list mutually agreed upon whose assays shall be final if within the limits of the assays of the two parties; and if not, the assays of the party nearer to the umpire shall prevail. Losing party shall pay cost of umpire. In case of Seller's failure to make or submit assays, Buyer's assays will govern.

4. The rates quoted herein are for carload lots. On truck shipments and/or any lot containing less than 20 tons there will be a handling charge of $25.00.

5. In this schedule where the word "ton" is used, it is understood to be a ton of two thousand pounds avoirdupois; where the word "ounce" appears, as referring to gold and silver, it is understood to mean the troy ounce; and where the word "unit" is used, it is understood to mean one percent of a ton, or twenty pounds avoirdupois.

6. The rates quoted herein are based on present published all rail freight rates on copper bullion from plant to New York City. Any increase or decrease is for account of Seller and proper deduction or credit will be made accordingly.

7. Seller should consign his shipment to -- Buyer, Plant location. It is required that the original bill of lading covering each such shipment be delivered to the Buyer promptly on release of the shipment to the carrier. Full details as to the disposition of settlement returns, including royalty instruction if any, must be furnished by Seller to Buyer before shipments can be processed.

8. Performance of this agreement is subject to any delays caused by strikes or other disabling causes beyond the control of either party.

9. All freight and other charges paid by Buyer for Seller's account will be considered as an advance payment and will be subject to an interest charge. Such interest shall be charged from the date of the advance payment to the date of final settlement at a rate of 1.2 times the rate quoted to Buyer from time to time by the bank.

LEAD CONCENTRATES

Analysis	Price
Au — 0.03 oz./T.	$150/oz.
Ag — 200 oz./T.	$4.50/oz.
Cu — 0.2%	85¢/lb.
Pb — 60%	24.5¢/lb.
Payments	
Au — (.03-.02) (.925) = .00925 ($150.00-$.50) =	$ 1.38
Ag — (200-1) (.95) = 189.05 ($4.50-$.06) =	839.38
Pb — (60-1.5) (.95) (20) = 1111.5 ($.245-.047) =	220.08
Cu — No payment	
	$1060.84/ton
Base charge $35/ton	
Assume no escalation in labor	
Assume no change in bullion freight rates	
F.O.B. smelter value	$1025.84/ton

NOTE: Freight to smelter is for the account of the mine.

COPPER CONCENTRATES

Analysis	Price
Au — .002 oz./T.	$150/oz.
Ag — 3.0 oz./T.	$4.50/oz.
Cu — 25%	85¢/lb.
Payments	
Au — No payment	
Ag — (3-1) (.95) = 1.9 ($4.50-.06) =	$ 8.44
Cu — (25-1) (.975) (20) = 468 ($.85-.076) =	$362.23
	$370.67/ton
Base charge $35/ton	
Assume no escalation in labor	
Assume no change in bullion freight rates	
F.O.B. smelter value	$335.67/ton

NOTE: Freight to smelter is for the account of the mine.

of the materials offered. Pacific Smelting Company, Torrance, California, reported itself as one of the nation's largest consumers of zinc scrap metals — but no ores — purchasing on a flat-price basis. Simmons Refining Company, Chicago, Illinois, seeks high-grade gold and silver concentrates; schedules call for payment of 98% of gold or silver content at specified times after receipt of the concentrate. The governing prices are those established on specified recognized metal or commodity exchanges. This firm indicated the possibility by mutual consent of variation of pricing, settlement dates, and market percentages, based on quantity and frequency of shipment. The company further noted that its schedules on lower grade materials would vary with content, impurities, and quantity and would be subject to change without notice.

American smelting operations have been subjected to emissions controls that are generally very strict. Thus, the use of new processes intended to accomplish compliance is one approach; another is to develop additional capacity in other countries, because adding control equipment to existing facilities in the United States is uneconomic. The demands placed upon the industry through explicit governmental standards are costly, and consequently, investment expenditures to meet these requirements, important as these are for pollution control, are not adding to productive capability. The uncertainty of the impact of regulations on the use of land, as well as the decreased demand for some mineral commodities, has had a disquieting effect upon American smelter operations. Curtailments of these vital operations are a blow to existing smaller exploration establishments because the availability of smelter services and facilities are an essential feature of the process of minerals marketing.

SALE OF NONMETALLIC MINERALS

Most nonmetallic minerals fall into one or the other of two categories for which determination of an average or representative price is virtually impossible. One includes materials classified by a complex grading system, the other includes materials mined almost exclusively by the user.

Some minerals, such as mica and asbestos, have various special uses, for each of which the individual user establishes diverse physical, chemical, or other specifications on which the price is based. Prices may range from a few cents to several dollars a pound, depending on the grade, and only an expert can properly classify the material as to grade. Furthermore, at least some processing is necessary to meet a given set of specifications or to produce material of one definite grade, and the value so added is included in the quoted price. Run-of-mine material may be worth very much less.

The other category includes very common materials, such as gypsum and limestone. Grades and specifications are virtually standardized, but factors completely dissociated from the nature of the material determine the value of a particular deposit. Because such materials are common, they are fairly cheap; transportation for any great distance might double the cost, hence location close to a market is essential. Accessibility and a nearby supply of cheap fuel are additional requirements. Most deposits of such materials are mined by the user himself, that is, in so-called captive mines. 'Prices' are not set by actual arms-length transactions but are arbitrarily established by the producer-consumer, basically for interdepartmental accounting and for taxation, hence they are more or less fictitious. Conceivably a prospector could sell an entire deposit of such material but could not mine the material and sell it by the carload.

Would-be producers of certain commodities face other problems besides uncertainty as to the grade or price of their product. These will be discussed in connection with the individual commodity involved.

For a concise analysis of supply and demand, sources, uses, processing methods, problems, prospects, and progress of research on any mineral commodity, refer to the "Minerals Yearbook", and, published annually by the U.S. Bureau of Mines. A more comprehensive but older analysis is included in "Mineral Facts and Problems", U.S. Bureau of Mines Bulletin 585. For a list of possible purchasers of minerals and metals, consult the latest annual Catalog, Survey & Directory Number of "Mining World".

TRANSPORTATION

Moving mineral products by rail or truck involves a cost factor of significance. It is incumbent upon the producer, who basically is buying a cubic foot of space, to obtain as low a rate as possible. Freight rates are estimated to have risen about 28% between January 1, 1974, and July 1, 1975.

Although the United States Interstate Commerce Commission regulates transportation rates in interstate commerce, it permits variations in the established rates if equipment moves in a 'back-haul' direction. Rather than have the equipment return to the point of origin either empty or only partly loaded, carriers may negotiate rates with the individual producers on specific commodities such as ore and mining equipment. This possibility bears investigation by the small producer.

Shipment by interstate waterways including Alaska and Hawaii is regulated by the Federal Maritime Commission; or, if the shipment is intrastate only, by a state commission. Most goods shipped by water are bulky, and many shipments are now containerized.

Published rates are usually expressed in cents per 100 pounds or per ton of 2,000 or 2,240 pounds. The volume of material to be moved, the frequency of movement, the origin of and the destination for the material, and current rates are all considered in relation to the Standard Commodity Code Number used by both railroads and trucks. This code lists, by division and category, the existing rates applying to all commodities and is open for inspection by the shipper. Shipped items generally move at commodity rates that are a percentage of first-class rates. Additional variations may appear among the territories into which the country is divided. Of course, finally determined rates are based on the carrier's margin of profit.

The services of private rate-service companies are available to help a shipper to obtain the best possible negotiated rate. These firms will check carrier rates and bills presented to the shipper, suggest appropriate material descriptions for bills of lading, assist in establishing a routing guide, and participate in actual rate negotiations. Such services may result in a reimbursement to the shipper, but the rate-service firm must be given access to information in bills of lading and relating to operations of the shipper. The fee is negotiable but is more likely to be based on the realized reimbursement. Contact with such firms may be made through persons engaged in freight traffic in the nation's larger cities.

Transportation cost may also be reduced through the activities of shipper's associations, which undertake to combine less-than-carload shipments so as to 'make a car' from a particular point of origin to a larger city with the least number of product transfers. Carload freight is loaded by the shipper and unloaded by the consignee whereas less-than-carload freight (LCL) is loaded and unloaded by the railroads. The individual shipper would pay the less-than-carload rate from his shipping point to the place of product consolidation. The point of division of the carload lot would usually be a major terminus close to the individual operation.

Familiarity with the operations and services of such agencies as the Rocky Mountain Freight Bureau, Denver, may prove valuable. This particular Bureau represents all major truck operators in the area.

Accompanying freight movements are bills of lading, which are binding contracts between shippers and carriers and which provide for the movement of goods from one location to another and arrival of the material in the same condition as when originally shipped. A copy of a bill of lading is provided as Figure 10-7.

The individual shipper should check which carriers are available to him and should seek information about the reliability, financial condition, and liability coverage of each carrier being considered. Normally, the carrier carries its own insurance. The shipper should also be aware of the nature and extent of government regulations affecting the carrier. The unregulated 'gypsy' trucker, for example, is a true menace to all regulated transport agencies. The shipper may protest to a regulating body if he feels wronged by the carrier.

Transportable commodities have special characteristics that affect their major mode of transportation. Table 10-4 categorizes various commodities according to the importance of their place value. For example, classified items of sand, gravel, and crushed stone have relatively low value, are moved generally only short distances, and loss and damage associated with their movement are both negligible. Thus, the common movement of these items is by truck and for local consumption, although water transport is also utilized because of the bulk. Fertilizers and fertilizer materials are also bulky and are mainly moved by truck; when rail transport is employed, special weather-tight cars may be necessary for protection of the material. Ores of nonferrous metals such as copper may be moved in open-top rail cars or box cars. The principal movement of this major commodity is intrastate from mines to smelters in Arizona, Utah, and Montana. Again, loss and damage are not particularly significant. Truck transport, conversely, is not of major significance in the movement of copper and other nonferrous metals. "Rates on aluminum, copper, lead, zinc . . . — and the ores from which they are obtained are on fixed or prescribed basis, and generally are not made on any distance scale or with any relation to class rates. Commodity rates are published between most of the points — which are relatively few in number — where there is a regular movement." (Association of American Railroads, 1947, p. 175.)

The 1973 report of the U.S. Secretary of the Interior included reference to a belief that the availability of reliable transportation in the United States has fallen behind the national demand for such service, and this lag has had serious adverse effect upon the country's mineral industries. Significantly, the report noted the need for development of coordinated plans by government and industry to facilitate the movement of large volumes of low-value materials and other items. Interestingly, the report emphasized the national need for deep-water ocean ports for bulk carriers as well as improved barge, rail, and other transportation mechanisms (U.S. Secretary of the Interior, 1973, p. 6).

STOCKPILING

When World War II seemed imminent, Congress passed the Strategic Materials Act of 1939 and appropriated $100,000,000 to establish a national stockpile of war materials deemed critical

TABLE 10-4.—Relative importance of place value.

Place value paramount	Place value of lesser importance	Place value of low importance
Clays (low-grade)	Barytes	Asbestos
Crushed stone	Diatomite	Bauxite
Gypsum	Feldspar	Bentonite (swelling type)
Limestone and lime (ordinary grades)	Kaolin (high-grade)	Beryl
Pumice	Limestone and lime (special grades)	Borates
Sand and gravel	Magnesite	Fluorspar
	Phosphate rock	Fuller's earth
	Potash salts	Garnet (abrasive)
	Pyrophyllite	Graphite
	Salt	Lithium minerals
	Special sands	Sheet mica (high-grade)
	Sodium salts	Quartz crystals
	Talc (ordinary grades)	Sulfur
	Vermiculite	Talc (steatite grade)
		Zircon

(Robie, 1959, p. 305. Reprinted by permission of AIME.)

and strategic. Thus, the Government of the United States entered the marketplace as a purchaser — and also later as a seller — of a variety of commodities. The actions of Government were motivated by two prime objectives: to supplement available domestic supplies and to prevent metals and materials required for war from falling into enemy hands.

Two government corporations were established to purchase these materials. Purchases were made from such countries as Argentina, Bolivia, Brazil, China, and Mexico.

Later legislation, such as the Strategic and Critical Materials Stockpiling Act of 1946, reemphasized the accumulation to stocks of materials and the building up of domestic production. Later the Commodity Credit Corporation was " . . . authorized upon terms and conditions prescribed or approved by the Secretary of Agriculture, to accept strategic and critical materials produced abroad in exchange for agricultural commodities acquired by the Corporation. Insofar as practicable, in effecting such exchange of goods, normal commercial trade channels shall be utilized and priority shall be given to commodities easily storable and those which serve as prime incentive goods to stimulate production of critical and strategic materials . . . Strategic and critical materials acquired by Commodity Credit Corporation in exchange for agricultural commodities shall, to the extent approved by the Munitions Board of the Department of Defense, be transferred to the stockpile provided for by the Strategic and Critical Materials Stock Piling Act; . . ." (Code of Federal Regulations, 1964, Title 15, sec. 714b, subsec. h.)

In the 1953 legislation providing for Domestic Minerals Program Extension, Congress declared, "It is recognized that the continued dependence on overseas sources of supply for strategic or critical metals and minerals during periods of threatening world conflict or political instability within those nations controlling the sources of supply of such materials gravely endangers the present and future economy of the United States. It is therefore declared to be the policy of the Congress that each department and agency of the Federal Government charged with responsibilities concerning the discovery, development, production and acquisition of strategic or critical minerals and metals shall undertake to decrease further and to eliminate where possible the dependency of the United States on overseas sources of supply of each such material." Additional funds were appropriated for stockpiling purposes.

In early 1960, the Office of Civil and Defense Mobilization indicated that both the reduction of commitments for the acquisition of various materials and the disposal of some of the items were under way. By 1962, both basic and maximum stockpile objectives had been reached in almost all categories. The stockpile had become a source of supply rather than a recipient of commodities.

The stockpile now contains 109 different commodities, most of which are ores, minerals, and metals. Among the materials in the national stockpile as of December 31, 1972, were aluminum, antimony, asbestos, bauxite, bismuth, cadmium, cobalt, columbium, copper, lead, magnesium, mercury, molybdenum, platinum group (iridium, palladium, platinum), rutile, selenium, silver, tantalum, tin, vanadium, and zinc. These materials are reported by the Office of Emergency Preparedness (American Bureau of Metal Statistics, 1973, p. 152).

The June 30, 1974, inventory of stockpile material provided by the General Services Administration indicated that the 109 commodities included in this total list are designated by specific grade, type, and unit of measure. The value of the total inventory according to this report exceeded $7,771,000,000 and a further objective was to reduce this value to about $1,182,000,000. Legislation has been requested that would permit the sale of excess commodities from the stockpile inventory that have a total accumulation valued at $5,059,123,000. Commodities having no stockpile objective are asbestos (crocidolite), celestite of nonstockpile grade, diamond tools, kyanite-mullite, magnesium, mica (muscovite block stained and lower), mica (scrap), rare earths, selenium, sperm oil, and talc (steatite grade).

Various news releases issued by the Office of Information, Office of Stockpile Disposal, General Services Administration, Washington, D.C., indicate that in the period February 1973 to May 1974 offers to sell certain materials from the national stockpile were announced. Celestite ore, ferrovanadium, rare earth chlorides, columbium oxide powder, kyanite and synthetic mullite, crude aluminum oxide, cadmium, antimony, natural rubber, lithium hydroxide, chromium metal, industrial diamond stones, rutile ore, molybdenum disulphide, pig tin, tungsten concentrate, slab zinc, pig lead, thorium nitrate, magnesium, selenium powder, kyanite ore, industrial diamond crushed bort, cobalt metal, mercury, copper in various forms, mangenese dioxide, tantalum pentoxide, ferromanganese, and silver were among the items about which news releases were distributed. Information about quantities sold, number and names of firms bidding, successful bidders, and prices by grade or categories and locations of the government-held materials were included in the releases.

In a review of the silver market for 1973, Handy and Harman noted that the national government had proposed in that year legislation authorizing the stockpile objective for silver to be set at 22,000,000 ounces, thereby permitting the sale of 117,000,000 ounces of silver from the national stockpile. This sizable release would constitute a significant increase in supply.

It is interesting to note that one news release in December 1973, relating to tin sales, indicated that the General Services Administration would continue its daily sales of tin but in a manner intended to minimize the effects of such sales on the world market for tin by offering larger quantities of tin when demand was strong, and reduced quantities when demand lessened. Its market actions would be designed to avoid impairing the health and growth of the world's tin industry.

In July 1974, in another news release, sales of surplus strategic materials were reported as exceeding $2,000,000,000 during the fiscal period July 1, 1973, to June 30, 1974. This was almost four times the value of sales in the proceeding fiscal year. Only in fiscal 1966 did sales exceed $1,000,000,000. The extensive sales in 1974 were reported as reflecting a response to President Nixon's program to reduce substantially the existing stockpiled materials no longer required for national defense. The sales of certain materials no longer required for national defense. The sales of certain materials were reported to have relieved hardships associated with their supply and to have lowered prices paid by the United States industry in both domestic producer and consumer sectors.

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ESSENTIAL INFORMATION REQUIRED FOR LOANS TO PRODUCERS OF MINERALS, METALS, FUEL EXCEPT OIL, AND GAS (MINING LOANS)

Name and Address of Applicant *(Street, City, County, State, ZIP CODE)*	*The information required by this form is the essential minimum necessary for proper evaluation and just consideration of Mining loan applications, because the economic recovery of minerals require special attention to factors not usually found in other types of business. These minimum requirements may be supplemented by any additional information which the applicant wishes to present in order to better show the economic feasibility of the mining or mineral project. Some information is repeated from that presented on other forms so that this form may be used independently.*
Telephone No.	*The Evaluation of Mining Loans will be Delayed if Essential Information is Lacking or Found Incorrect on Checking.*

Complete the following, where applicable - Attach additional sheets, if more space is needed.

1. Location of underground mine, open cut or strip pit, quarry, mill, washery, breaker or other treatment plant. The location should include distances from nearest town, paved highway, railroad or other means of transportation such as water, if available.

2a. Minerals (oxide, sulphide or non-metallic), coal or other material mined. Common or descriptive names as used by industry for minerals and products should be used. Coal may be described by the same name in which it i

b. Products produced by milling, concentrating, washing, breaking or other treatment.

3. Reserve of minerals or materials to be mined (ore, coal, clay or others). The applicant's estimate of Reserves should be given including computations showing how the estimate was made. The grade, quality or cleanliness of each mineral material, ore, coal or non-metalic (such as limestone, gypsum, silica, shale, clay and stone), should be stated. In additior., the approximate percent of recovery should be estimated.

SBA Form 4B (4-66) EDITION OF 3-65 MAY BE USED UNTIL STOCK IS EXHAUSTED.

FIGURE 10-3. — Small Business Administration Form 4B.

4. **Description of operation, present and proposed future.** The applicant's principal representative, President, General Manager or operator should describe the past, present and proposed future operation in his own words. Local mining terms of the area may be used in telling about the mine and plant methods of production. If underground, the means (tunnels or shafts) of reaching the working places should be mentioned as well as the method of breaking and removing the material being mined. The size and availability of any needed stockpile or waste area and tailing ponds should be included with the plant description. The hauling distance for material or ore and products to market should be shown. Faulting, bad ground, bands of waste material in coal, excessive water, need for unusual timbering or roof bolting and any other operating problems should be detailed. If a change in mining or processing is desired, it should be stated and the reasons should be given. For example, the change could be to a different mining or processing method, to the use of additional or more efficient equipment, to move to another working place, or to open a new mine.

a. **Mining Method.**

b. Milling or treatment method.

SBA Form 4B (4-66)

2 of 4

FIGURE 10-3. — Small Business Administration Form 4B (Continued).

4.

c. **Operating Problems or Reasons for desired change, if any.**

5. **Operating costs, selling prices of product.** If available, past and present costs per ton or other unit of product sold should be given. The proposed operation should show each man listed according to the principal work to be performed, or machine to be operated per shift, or other period and the production of finished product expected from the same period of time. The overall cost of production of product per ton or other unit should be indicated by adding the proportional part of supervision, royalty and other overhead costs. The price or prices received and to be received for the product per ton or unit less selling expense of past, present and future as far as known, should be stated for comparison. The market for the product or products to be produced should be given in detail, showing transportation distances and relation with competitors, if any.

FIGURE 10-3. — Small Business Administration Form 4B (Continued).

6. **Other pertinent information and management.** The availability of needed utilities and facilities (electric power, water, roads, railroads, etc.) giving sizes, capacities, or other conditions which apply. The weather as it affects operation should be stated. The qualifications, experience and ability of the manager, supervisors and operators should be summarized.

7. **List of supporting papers and reports and references.** Attachments of supporting information should be listed. These may include engineering reports, maps, sketches, smelter settlement sheets, drill hole logs, sampling and assaying results, test reports, letters showing availability of material or machinery and markets if available. References may be made to U. S. Geological and Bureau of Mines publications and maps or other government or state publications and technical magazines. A summary of the qualifications of engineers, whose reports are used, should be included.

Collateral grouped separately for the **mine, plant** and **"to be acquired"** should be listed on SBA 4 Schedule A sheets according to the instructions on SBA Form 4A.

SBA Form 4B (4-66) 4 of 4 GPO 869-568

FIGURE 10-3. — Small Business Administration Form 4B (Continued).

SMALL BUSINESS ADMINISTRATION

APPLICATION FOR LOAN

(See Instructions on Page 2)

SBA LOAN NUMBER

1. APPLICANT (Show official name without abbreviations unless an abbreviation is a part of the official name. For proprietor or partnership, show name(s) followed by d/b/a and trade name used, if any)

Name		Street		
City	County	State	ZIP Code	Tele. No.
Employer's I.D. Number	Date of Application	Amount of Loan Requested	Maturity Requested	
Type of Business		Date Established	Number of Employees (Including subsidiaries and affiliates). At Time of Application ______ If Loan is Approved ______	
Franchise ☐ Yes ☐ No If Yes, Submit Copy		☐ Existing Business ☐ New Business		

2. Use of Proceeds:

Land Acquisition	$ ______	Acquisition and/or repair of machinery and equipment	$ ______
New Building or plant construction	$ ______	Working Capital	$ ______
Debt Payment	$ ______	Other	$ ______
		Total	$ ______

3. SUMMARY OF COLLATERAL OFFERED (Attach detailed list of collateral offered - See Item 8(16), page 2)

	Cost	Net Book Value (Cost Less Depreciation)	Present Liens Or Mortgage Balance, If Any
Land and Buildings			
Business machinery and equipment. .			
Business furniture and fixtures			
Accounts receivable			
Inventory			
Other (specify)			

4. AS ADDITIONAL SECURITY, PAYMENT OF THE LOAN WILL BE GUARANTEED BY:

Name and Address (Include ZIP Code and Social Security Number of Guarantors) (Each principal must submit a signed persoanl balance sheet as of the same date as the applicant's balance sheet)	Net Worth Outside Of Interest In Applicant Company
	$

5. DISCLOSURE OF SPECIAL INFORMATION REGARDING PRINCIPALS: (a) List below the names of any SBA employees or SBA advisory board members who are related by blood, marriage or adoption to, or who have any present or have had any past, direct or indirect, financial interest in or in association with, the applicant, or any of its partners, officers, directors or principal stockholders (such interest to include any direct or indirect financial interest in any other business entity or enterprise); (b) When the proprietor, or any partner, officer, director, or person who holds 10 percent or more of the applicant's stock is an investor in a licensed Small Business Investment Company, or a proposed investor in an SBIC which has filed for a license, detailed information shall be submitted with this application; and (c) Likewise, if any person identified in (b) above, or their spouse, is an employee of the U.S. Government (including members of the armed forces), detailed information shall be submitted with this application. (Use separate sheet if necessary).

If none, check here: ☐ (a) ☐ (b) ☐ (c)

Name and Address (Include ZIP Code)	Details of Relationship or Interest

6. MANAGEMENT (1) Names of all owners, officers, directors or partners and their annual compensation, including salaries, fees, withdrawals, etc. (complete all columns). (2) Names and compensation of all employees receiving in excess of $17,500 annually. (3) All stockholders having a 20% or more interest in applicant (complete all columns except annual compensation). (4) Hired manager.

Name (List first, middle, maiden & last.) (If no middle name, so state) Home Address (Include ZIP Code)	Office Held	Annual Compensation	Percent Ownership	Personal Guaranty Offered (Yes or No)	Insurance Carried for Benefit of Applicant*

*Life insurance on owner(s) or principal(s) will be required ONLY when specifically included as a condition of an approved loan.

7. RECENT EFFORTS TO OBTAIN CREDIT (For Direct Loan Applicants Only): The SBA is authorized to make loans to business enterprises only when the financial assistance is not otherwise available on reasonable terms. SBA is also empowered to make loans in cooperation with banks or other lending institutions through agreements to participate on an immediate or guaranty basis. Therefore, applicant must furnish the information required below regarding efforts made within 60 days preceding the filing of this application to obtain credit from banks of other sources. Letters declining to extend credit as well as declining to participate with SBA must be obtained from the following lending institutions: (a) The applicant's bank of account; and (b) if the amount of the loan applied for is in excess of the legal lending limit of the applicant's bank or in excess of the amount that the bank normally lends to any one borrower, then a refusal from a correspondent bank or from any other lending institution whose lending capacity is adequate to cover the loan applied for (c) letters from two banks are required if applicant is located in a city with a population in excess of 200,000. These letters must contain date of application, amount of loan requested and reasons for refusal, and be attached to this application.

CREDIT INFORMATION - Applicant expressly authorizes disclosure of all information submitted in connection with this application and any resulting loan to the financial institution agreeing below to participate in such loan or, if none, to its bank(s) of account and (Insert name of other financial institution if desired) ______

PARTICIPATION - Will any lending institution participate with SBA in the loan requested? ☐ Yes ☐ No. If "Yes" institution shall execute Application For Participation or Guaranty Agreement at bottom of page 4.

PAGE 1 OF

SBA FORM 4 (11-71) REF: ND 510-1A REPLACES APPLICATION FOR LOAN PARTS OF SBA FORMS 4 PART 1, 4A, 6B, 527, 528A, AND 751 ALL OF WHICH ARE OBSOLETE. ALSO INCORPORATES REQUIREMENTS CONTAINED IN FORMS 394, 652 AND 652B.

FIGURE 10-4. — Small Business Administration Form 4.

8. INSTRUCTIONS TO APPLICANT

Direct Loans - Submit one copy of this form and all supporting documents to SBA.

Participation Loans - Submit two copies of this form and all supporting documents to the participating bank.
All attachments must be signed and dated.

(1) SBA Form 912 must be submitted in quadruplicate by the proprietor, if a sole proprietorship; by each partner, if a partnership; by each officer, director, and each holder of 20 percent or more of the voting stock, if a corporation; and other person, including a hired manager, who has authority to speak for and commit the borrower in the management of the business. In addition, applicant must submit a signed copy of SBA Form 641, "Request for Counseling," with the application.

(2) Attach to application a brief description and history of the business.

(3) Comment briefly on the benefits the business will receive if the loan is obtained.

(4) Attach a schedule on all installment debts, contracts, notes and mortgages payable, showing to whom payable, original amount, original date, present balance, rate of interest, maturity date, monthly payment, security and whether current or delinquent. (Amounts on this schedule should agree with the figures on the applicant's financial statement.) Indicate by an asterik (*), items to be paid by loan proceeds and reason for paying same.

(5) If construction is involved, state the estimated cost, source of any additional funds which may be required to complete the construction and whether temporary financing for the construction is available. Furnish preliminary plans and specifications with the application. Final plans and specifications must be submitted for SBA/Lender approval prior to commencement of construction if loan is approved.

(6) Where loan funds will be used for construction purposes, and the contract or subcontracts are in excess of $10,000, the Applicant must execute and submit with the application "Applicant's Agreement of Compliance," SBA Form 601, which is a non-discrimination agreement issued pursuant to Executive Order 11246.

(7) Where purchase of machinery and equipment is involved, furnish a detailed list of items to be purchased and the estimated cost thereof.

(8) For each person listed in "Management" give brief description of education, technical training, employment and business experience.

(9) Attach balance sheets for the past 3 fiscal years.

(10) Attach balance sheet dated within 90 days from date of filing application with aging of accounts receivable and payable.

(11) Attach Profit and Loss Statement for past three fiscal years and for as much of current year as is available. (If operating statements are not available, explain why not and enclose corresponding Federal income tax returns in lieu thereof.) If past earnings do not show ability to repay proposed loan and existing obligations, attach an estimated profit and loss statement for at least one full year.

(12) Reconciliation of net worth shall be provided for items (9) and (10) above.

(13) If new business, furnish earnings projection (estimated profit and loss statement) for at least one full year.

(14) Personal Financial Statements must be submitted for proprietors, each partner, each officer, and each stockholder with 20% or more ownership. (For this purpose the enclosed SBA Form 413 may be used.)

(15) Details must be given of any pending litigation, whether applicant be plantiff or defendant or any litigation that involves management of the applicant.

(16) A description of collateral is required. Attached SBA Forms may be used for this purpose. SBA/Bank may require submission of an appraisal.

(17) SUBSIDIARIES AND AFFILIATES - List on an attached sheet the names and addresses of (1) all concerns that may be regarded as subsidiaries of the applicant, including concerns in which the applicant holds a controlling (but not necessarily a majority) interest, and (2) all other concerns that are in any way affiliated, by stock ownership or otherwise, with the applicant. The applicant should comment briefly regarding the trade relationship between the applicant and such subsidiaries or affiliates, if any, and if the applicant has no subsidiary or affiliate, a statement to this effect should be made. Signed and dated balance sheets, operating statements and reconcilement of net worth must be submitted for all subsidiaries and affiliates.

(18) PURCHASE AND SALES RELATIONS WITH OTHERS - Does applicant buy from, sell to, or use the services of, any concern in which an officer, director, large stockholder, or partner of the applicant has a substantial interest?
☐ Yes ☐ No If "Yes" give names of such officers, directors, stockholders, and partners, and names of any such concern on attached sheet.

(19) RECEIVERSHIP - BANKRUPTCY - Has applicant or any officer of the applicant or affiliates or any other concern with which such officer has been connected ever been in receivership or adjudicated a bankrupt?
☐ Yes ☐ No If "Yes" give names and details on separate sheet.

(20) Previous Government Financing - List assistance received, or requested and refused, and any pending applications.

Name of Agency or Department (including SBA)	Amount Approved or Requested	Date of Approval or Request	Present Balance	Status (Current, Delinquent, Maturity Accelerated)

SBA FORM 4 (11-71) PAGE 2 OF 4

FIGURE 10-4. — Small Business Administration Form 4 (Continued).

9. POLICY AND REGULATIONS CONCERNING REPRESENTATIVES AND THEIR FEES An applicant for a loan from SBA may obtain the assistance of any attorney, accountant, engineer, appraiser or other representative to aid him in the preparation of his application to SBA; however, such representation is not mandatory. In the event a loan is approved, the services of an attorney may be necessary to assist in the preparation of closing documents, title abstracts, etc. SBA will allow the payment of reasonable fees or other compensation for services performed by such representatives on behalf of the applicant.

There ar no "authorized representatives" of SBA, other than our regular salaried employees. Payment of any fee or gratuity to SBA employees is illegal and will subject the parties to such a transaction to prosecution.

SBA Regulations (Part 103, Sec. 103.13-5(c)) prohibit representatives from charging or proposing to charge any contingent fee for any services performed in connection with an SBA loan unless the amount of such fee bears a necessary and reasonable relationship to the services actually performed: or to charge any fee which is deemed by SBA to be unreasonable for the services actually performed; or to charge for any expenses which are not deemed by SBA to have been necessary in connection with the application. The Regulations (Part 122, Sec. 122.19) also prohibit the payment of any bonus, brokerage fee or commision in connection with SBA loans.

In line with these Regulations SBA will not approve placement or finder's fees for the use or attempted use or influence in obtaining or trying to obtain an SBA loan, or fees based solely upon a percentage of the approved loan or any part thereof.

Fees which will be approved will be limited to reasonable sums for services actually rendered in connection with the application or the closing, based upon the time and effort required, the qualifications of the representative and the nature and extent of the services rendered by such representative. Representatives of loan applicants will be required to execute an agreement as to their compensation for services rendered in connection with said loan.

It is the responsibility of the applicant to set forth in the appropriate section of the application the names of all persons or firms engaged by or on behalf of the applicant. Applicants are required to advise the SBA Field Office in writing of the names and fees of any representatives engaged by the applicant subsequent to the filing of the application.

Any loan applicant having any question concerning the payment of fees, or the reasonableness of fees, should communicate with the Field Office where the application is filed.

10. NAMES OF ATTORNEYS, ACCOUNTANTS, AND OTHER PARTIES. The names of all attorneys, accountants, appraisers, agents, and all other parties (whether individuals, partnerships, associations or corporations) engaged by or on behalf of the applicant (whether on a salary, retainer or fee basis and regardless of the amount of compensation) for the purpose of rendering professional or other services of any nature whatever to applicant, in connection with the preparation or presentation of this application to Bank in which SBA may participate or any loan to applicant as a result of this application; and all fees or other charges or compensation paid or to be paid therefor or for any purpose in connection with this application or disbursement of the loan whether in money or other property of any kind whatever, by or for the account of the applicant, together with a description of such services rendered or to be rendered, are as follows:

Name and Address (Include ZIP Code)	Description of Services Rendered and to be Rendered	Total Compensation Agreed to be Paid*	Compensation Already Paid*

*Enter specific dollar amounts. "Unknown," "Undetermined" or other emprecise terms are not sufficient.

11. AGREEMENT OF NONEMPLOYMENT OF SBA PERSONNEL. In consideration of the making by SBA to applicant of all or any part of the loan applied for in this application, applicant hereby agrees with SBA that applicant will not, for a period of two years after disbursement by SBA to applicant of said loan, or any part thereof, employ or tender any office or employment to, or retain for professional services, any person who, on the date of such disbursement, or within one year prior to said date, (a) shall have served as an officer, attorney, agent, or employee of SBA and (b) as such, shall have occupied a position or engaged in activities which SBA shall have determined, or may determine, involve discretion with respect to the granting of assistance under the Small Business Act, or Economic Opportunity Act or said Acts as they may be amended from time to time.

12. CERTIFICATION, I hereby certify that:

(a) The Applicant has read SBA Policy and Regulations concerning representatives and their fees (#9 above) and has not paid or incurred any obligation to pay, directly or indirectly, any fee or other compensation for obtaining the loan hereby applied for.

(b) The applicant has not paid or incurred any obligation to pay to any Government Employee or special Government employee any fee, gratuity or anything of value for obtaining the assistance hereby applied for. If such fee, gratuity, etc. has been solicited by any such employee, the applicant agrees to report such information to the Office of Security and Investigations, SBA, 1441 L Street, N. W., Washington, D. C. 20416.

(c) All information contained above and in exhibits attached hereto are true and complete to the best knowledge and belief of the applicant and are submitted for the purpose of inducing SBA to grant a loan or to participate in a loan by a bank or other lending institution to applicant. Whether or not the loan herein applied for is approved, applicant agrees to pay or reimburse SBA for the cost of any surveys, title or mortgage examinations, appraisals, etc., performed by non-SBA personnel with consent of applicant.

(d) The applicant hereby covenants, promises, agrees and gives herein the Assurance as required by 13 CFR 112.8 and CFR 113.4 that in connection with any loan to applicant which SBA may make, or in which SBA may participate or guaranty as a result of this application, it will comply with the requirements of Parts 112 and 113 of SBA Regulations and Title VI of Civil Rights Act of 1964 to the extent that said Parts 112 and 113 are applicable to such financial assistance, and further agrees that in the event it fails to comply with said applicable Parts 112 and 112, SBA may call, cancel, terminate, accelerate repayment or suspend in whole or in part the financial assistance provided or to be provided by SBA, and that SBA, or the United States Government may take any other action that may be deemed necessary or appropriate to effectuate the nondiscrimination requirements in said Parts 112 and 113, including the right to seek judicial enforcement of the terms of this ASSURANCE OF COMPLIANCE. These requirements prohibit discrimination on the grounds of race, color or national origin by recipients of federal financial assistance, including but not limited to employment practices, and require the submission of appropriate reports and access to books and records; these requirements are applicable to all transferees and successors in interest.

____
(Individual, general partner, trade name or corporation)

Corporate Seal

By ______________________________

Attest ______________________________ Title ______________________________
(Title)

Date Signed: ______________________________, 19 ______

Whoever makes any statement knowing it to be false, or whoever willfully overvalues any security, for the purpose of obtaining for himself or for an applicant any loan, or extension thereof by renewal, deferment of action, or otherwise, or the acceptance, release, or substitution of security therefor, or for the purpose of influencing in any way the action of the SBA, or for the purpose of obtaining money, property, or anything of value, under the Small Business Act, as amended, shall be punished under Section 16(a) of the Small Business Act, as amended, by fine of not more than $5,000 or by imprisonment for not more than two years, or both.

SBA FORM 4 (11-71) PAGE 3 OF 4

FIGURE 10-4. — Small Business Administration Form 4 (Continued).

13. APPLICATION FOR PARTICIPATION OR GUARANTY AGREEMENT

Bank Transit No.

(For use only by bank or other financial institution)

We propose to make a (check one):

☐ Guaranteed loan Bank Share ________ %, SBA Share ________ %.

☐ Immediate participation loan with bank to make and service, Bank Share ________ %, SBA Share ________ %.

To the Applicant named on page 1 of this application. We hereby make application for the type of participation agreement checked above subject to the following loan conditions (use separate sheet if necessary):

(1) Terms and Conditions:

(a) Term of loan _____ years. Monthly payments, including lender's interest at _____ % per annum, simple, in the amount of $________.

(b) Collateral and lien position.

(c) Guarantors

(d) Insurance: Life, Hazzard, Federal Flood.

(e) Other

(2) Participation: SBA prefers that a lender participate beyond the total existing debts owed the lender which are to be refinanced through the loan. Existing obligations owed to the lender may be refinanced through the loan, in accordance with the minimums set forth below, only when the lender certifies in writing that such debt is in good standing (payments and other obligations handled substantially as agreed) and is satisfactory in all respects. Lenders minimum share of a loan shall be:

(a) Guaranty - 10% for SBA loans and as currently applicable for Economic Opportunity Loans.

(b) Immediate Participation - 25% provided the legal lending limit permits; 10% for Economic Opportunity Loans.

(3) Interest Rate: Lender may establish its own interest rate provided it is legal and reasonable, subject to SBA's approval. If lender's interest exceeds 8 percent per annum (simple) on a guaranteed loan SBA will pay accrued interest to the date of purchase on its guaranteed portion at the simple annual rate of 8 per cent without any future adjustment for unpaid accrued interest in excess of this effective rate. Lender may use an add-on interest provided (i) State law permits; (ii) the face of the SBA Note shows the principal amount of the actual dollar amount disbursed or to be disbursed to the borrower under the loan and all other SBA documents show this amount of principal; (iii) interest is converted to a simple annual interest rate and such converted rate is shown on all SBA documents other than the note (The add-on interest rate should be specified on the Note, if necessary, to comply with State law; otherwise show the simple interest rate.)

(4) Comments of the Bank, which may be in the form of a letter or memorandum, shall:

(a) include an evaluation of ability of Applicant's management, its past record of handling obligations, your expression as to what the loan will do for applicant, applicant's repayment ability, and other pertinent information. If Applicant or any of its officers have been adjudicated a bankrupt or connected with a receivership or been involved in any criminal, or other legal proceedings, give details. Also include an appraisal of the collateral if available and your evaluation of its adequacy to secure the loan.

(b) state whether any officer, director or substantial stockholder of Bank has a financial interest in Applicant and, if so, the extent thereof;

(c) indicate whether Applicant, its subsidiaries or affiliates, is indebted to the Bank, the amount, terms, and how secured, including any guaranties, and whether applicant's loans have been met substantially as agreed. (Include all such loans made during the past 12 months, showing high and low credit by months. If no loans were made during the period, so state.)

(5) Without the participation of SBA to the extent applied for we would not be willing to make this loan. In our opinion, the financial assistance applied for is not otherwise available on reasonable terms.

____
Name and address of bank (Include ZIP Code)

Telephone No. ____________

Date ____________, 19____

____
Authorized Officer

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FIGURE 10-4. — Small Business Administration Form 4 (Continued).

MARKETS

Tungsten: GSA award ranges were up sharply, to $74.177-75.20 per short ton unit (domestic) and to $79.47-82.57 per stu (export), at the April 25 bid opening. GSA is increasing its release rate to 850,000 lb of tungsten per month due to strong demand.

Cadmium: The long-awaited US cadmium producer price increase finally came through last month. National Zinc led off on May 1, increasing its quote by 55¢ to $4.30 per lb. Other US and Canadian producers followed later in the month, but to only $4.25.

Nickel: Falconbridge hiked its cathode price by 23¢, to $1.85 per lb, on May 15, followed the next day by a Le Nickel increase to $1.78 per lb for ferronickel FN4. Dealer quotes were $2.25-2.50 near the end of May.

Silicon: European silicon prices have soared to $3,500-4,000 per metric ton, a 500% rise since mid-1973.

Silver: Continuing to be volatile, silver moved from Handy's quote of 554¢ on May 1 to 606¢ on May 14, which led to profit-taking and a quote of 537¢ on May 21. Sharps, Pixley vice president Edward Hoffstatter predicts that silver will drop to the $4 level sometime this year, then soar to $10 in 1976.

Selenium: Most US and Canadian selenium producers increased their quotes in May. Anaconda kicked off the action by raising its commercial grade selenium $3 to $18 per lb, effective May 1. Other producers followed, with Asarco and Noranda raising their high-purity grade selenium to $21 per lb, also up $3.

Tellurium: US tellurium producers, led by Anaconda on May 1, increased prices by $2, to $9 a lb.

Antimony: US antimony oxide producers hiked prices to $1.43-1.44 in May—up from $1.245.

Average prices May

(Metals Week quotations)

For daily prices, see p. 64

Cents per pound unless otherwise indicated.

Aluminum:	
Major US producer	31.500
MW US market	47.705
Copper:	
US producer, delivered	81.459
f.o.b. refinery	80.834
Major producer, c.i.f. Europe	130.504
f.o.b. Atlantic seaboard	127.640
MW New York dealer	126.477
Lead, US producer	21.500
Tin:	
New York market	456.875
MW New York dealer	451.091
Zinc:	
US producer, PW	34.784
European producer (£ per mt)	330.000
Gold, tr oz:	
Engelhard buying	$167.730
selling	$163.768
Handy & Harman	$163.566
Silver:	
H&H, NY, cents per tr oz	543.182
London Spot, pence per tr oz	222.307
Sterling Exchange (in dollars)	2.41368
Palladium, major prod., tr oz	$150.000
Platinum, major prod., tr oz	$170.000
Antimony:	
RMM, Laredo	175.000
Lone Star, Laredo	208.000
New York dealer	279.091
Bismuth, major producer	900.000
Cadmium, US producer	418.200
Cobalt, shot/cath., 250-kg lots	339.500
Magnesium, US primary ingot	55.000
Mercury, NY, per flask (76 lb)	$294.318
Nickel, major producer, cathode	162.000

Free Gold Market

Gold prices sagged in May on rumors of selling by central banks. Although denied by Rome, the Banca d'Italia was selling via Switzerland about 1 to 2 tons daily in order to finance Italy's gigantic trade deficit. Contributing to the overall price weakness was Washington's adamant opposition to a proposal by Common Market members to deal in gold among themselves at a price approaching free market levels.

From the final London fixing of $169.50 per tr oz at the beginning of May, the price slowly eroded, closing the month at $156.75—a 7½% decline. The down-trend was interrupted by a sharp rally when the US Senate approved gold ownership by US citizens, beginning Sept. 1.

Gold coin buying picked up on cheaper prices, then slowly tapered off. However, the Krugerrand (1 tr oz fine gold) remained in good demand.

Interest in gold futures dwindled in May. At month's end, London quoted $175.50 for one-year delivery, while Singapore listed $177.50. In Winnipeg, the July 1975 contract was trading at $179.00.

Gold sales in all international markets during May totaled approximately $1,900 million.

PICK'S WORLD CURRENCY REPORT:

	Coins Apr. 30	Coins May 31	Bars Apr. 30	Bars May 31
N. Y. Licensed Dealer	$ –	$ –	$170.00	$157.25
Manila	301.00	278.00	174.00	161.50
Hong Kong	234.00	212.00	171.50	160.00
Bombay	245.00	225.00	176.00	164.50
Beirut	238.00	217.00	171.00	157.00
Paris	324.50	251.00	182.00	164.00
Buenos Aires	222.00	205.00	170.00	159.00

Notes: Prices are quoted at the free or black market value of the US dollar in the local markets.

Miscellaneous Metals

Wholesale lots (a) f.o.b. ship pt.; (b) delivered; (c) f.o.b. N.Y.; (d) dep. on size of lot; (e) dep. on grade; (n) nom.

Aluminum: eff. 3-28-74	
unalloyed ingot, (b), lb	31.5¢
Antimony: (99.5%), bulk, lb., domestic, eff. 5-2-74	
RMM, f.o.b. Laredo	$1.75
Lone Star, f.o.b. Laredo	$2.08
Imported N.Y. (lb.) 5-ton lots, duty pd. 99.5%-99.6%	$2.70-3.00
Beryllium:	
rod, 5-in., (b), (d), lb	$106.05
Bismuth: lb. ton lots, eff. 4-8-74	$9.00
Cadmium: lb. eff. 5-7-74	
US producer	$4.25-4.30
Chromium: (b) lb. of material,	
aluminothermic 99.25%	$1.53
electrolytic 99.8%	$1.53
vacuum melting	$1.60
Cobalt: lb, (c) shot 99%+	
50-kg drums	$3.50
250-kg drums	$3.45
less than 50 kilograms	$3.55
Powder, 300 and 400 mesh, 50-kg drums	$4.54
extra fine, 125-kg drums	$5.63
S grade, 10-ton lots	$3.50
Columbium: 99.5-99.8%, (d), metallurgical roundel ...... $11-22 rough ingots	$16-27
Gallium: 99.999%, g, 5-10 kilo lots	80¢
Germanium: kilo (b), eff. 6-8-70	
Zone refined	$293.00

(Continued on p66; daily prices on p64)

FIGURE 10-5. — Engineering and Mining Journal Markets.

Metals Week Quotations

MAY 1974	COPPER (a) US Producer Delivered	COPPER (a) US Producer Refinery	COPPER (a) c.i.f. Europe	COPPER (a) Atlantic Seab'd	LEAD US Producer (b)	ZINC US PW (c)	SILVER US Producer (d)	TIN NY Market (e)
1	81.324	80.699	145.904	143.040	21.500	34.914	553.952	464.750
2	81.324	80.699	147.580	144.716	21.500	34.931	552.795	462.000
3	81.324	80.699	146.971	144.107	21.500	34.786	559.954	463.750
WK AVG	76.224	75.599	146.901	144.037	21.500	34.835	559.570	464.050
6	81.480	80.855	149.109	146.245	21.500	34.817	544.059	470.000
7	81.480	80.855	143.532	140.668	21.500	34.666	521.843	470.000
8	81.480	80.855	145.496	142.632	21.500	34.791	525.654	468.750
9	81.480	80.855	141.667	138.803	21.500	34.828	560.225	470.000
10	81.480	80.855	140.425	137.561	21.500	34.745	565.963	465.000
WK AVG	81.480	80.855	144.046	141.182	21.500	34.769	543.549	468.750
13	81.480	80.855	134.528	131.664	21.500	34.836	534.144	465.000
14	81.480	80.855	138.335	135.471	21.500	34.737	605.967	465.000
15	81.480	80.855	131.090	128.226	21.500	34.778	580.966	462.000
16	81.480	80.855	129.565	126.701	21.500	34.808	592.482	461.000
17	81.480	80.855	124.840	121.976	21.500	34.726	577.629	463.000
WK AVG	81.480	80.855	131.672	128.808	21.500	34.777	578.238	463.200
20	81.480	80.855	124.472	121.608	21.500	34.804	554.487	464.000
21	81.480	80.855	117.321	114.457	21.500	34.706	538.322	450.000
22	81.480	80.855	120.911	118.047	21.500	34.686	550.409	450.000
23	81.480	80.355	114.307	111.443	21.500	34.749	511.375	450.000
24	81.480	80.855	116.641	113.777	21.500	34.799	501.766	448.000
WK AVG	81.430	80.855	118.730	115.866	21.500	34.749	531.272	452.400
27	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY
28	81.480	80.855	118.315	115.451	21.500	34.839	466.978	434.000
29	81.480	80.855	110.190	107.326	21.500	34.774	471.804	427.000
30	81.480	80.855	114.576	111.712	21.500	34.781	507.484	438.000
31	81.480	80.855	115.311	112.447	21.500	34.757	498.469	440.000
WK AVG	81.480	80.855	114.598	111.734	21.500	34.788	486.134	434.750
AVERAGES FOR MONTH	81.459	80.834	130.504	127.640	21.500	34.784	539.851	456.875

Silver, Gold, Sterling

MAY 1974	SILVER (f) H&H, NY	SILVER (f) London Spot	STERLING EXCH. (g)	GOLD (h) London Final	GOLD (h) Engelhard Selling
1	554.000	223.200	2.41850	169.500	170.000
2	558.000	225.100	2.41900	169.650	170.150
3	564.000	227.200	2.41800	169.000	169.500
WK AVG	562.800	225.480	2.42230	169.330	169.830
6	545.000	224.500	2.43500	166.000	166.500
7	525.000	214.750	2.41550	163.000	163.500
8	527.500	216.300	2.43000	157.750	158.250
9	565.000	223.800	2.43050	166.250	166.750
10	566.000	224.800	2.43000	167.700	168.200
WK AVG	545.700	220.830	2.42820	164.140	164.640
13	582.500	229.400	2.42900	166.500	167.000
14	606.000	249.400	2.41850	166.250	166.750
15	581.000	234.200	2.42450	164.400	164.900
16	597.000	238.900	2.41250	164.000	164.500
17	578.500	238.800	2.41000	165.500	166.000
WK AVG	589.000	238.140	2.41890	165.330	165.830
20	554.000	232.600	2.40500	162.900	163.400
21	537.000	225.000	2.40600	161.000	161.500
22	553.500	225.000	2.41450	163.000	163.500
23	515.000	206.500	2.41150	159.500	160.000
24	497.000	216.600	2.40100	161.750	162.250
WK AVG	531.300	221.140	2.40760	161.630	162.130
27	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY
28	463.000	203.700	2.39300	154.000	154.500
29	475.000	193.000	2.39100	155.500	156.000
30	508.000	212.500	2.39200	162.000	162.500
31	498.000	205.500	2.39600	156.750	157.250
WK AVG	486.000	203.675	2.39300	157.063	157.563
AVERAGES FOR MONTH	543.182	222.307	2.41368	163.268	163.768

(a) **Copper** quotations are cents per lb. **MW US Producer Delivered:** Quotation is estimated weighted average based on US mine production and current selling prices of US producers, reduced to a delivered wirebar basis. Premium on special shapes, eff. in some instances on Jan. 15, 1971, is 0.75-0.85¢ a lb on cakes and 1.725-1.875¢ on billets. Discounts on cathodes are 0.375-1.250¢. **MW US Producer Refinery:** F.o.b. quotation is US Producer Delivered price minus 0.625¢ shipping cost, eff. May 1, 1971. **MW c.i.f. Europe:** Quotation is LME cash asked wirebar price. **MW Atlantic Seaboard:** Quotation is calculated by deducting shipping costs from the c.i.f. Europe price; eff. Jan. 3, 1972, 2.036¢ per lb is deducted (0.263¢ lighterage, 0.080¢ insurance, and 1.693¢ ocean freight).

(b) **Lead, MW US Producer,** cents per lb: Quotation is a weighted average based on fixed price sales of domestically refined lead sold by domestic producers to domestic consumers. Eff. Dec. 31, 1971, price is for common grade on a nationwide, delivered basis.

(c) **Zinc, MW US PW,** cents per lb: Quotation is a weighted average that reflects fixed-price sales of prime western zinc, as well as sales of other grades when sold on a prime western basis, by domestic producers to domestic consumers. Eff. Jan. 1, 1971, PW zinc is sold on a delivered basis.

(d) **Silver, MW US Producer,** cents per tr oz: Quotation is a weighted average reflecting worldwide sales of 0.999 fine silver reduced to a New York equivalent basis.

(e) **Tin, NY Market,** cents per lb: Quotation is consensus of New York dealers at noon each day for Grade A tin, delivered.

(f) **Silver,** cents per tr oz. **Handy & Harman NY:** Quotation is the lowest price at which offers can be obtained by H&H for silver in commercial bar form in accordance with ASTM designation B413-69 specification for refined silver, grade 99.90, for nearby delivery at New York, in quantities sufficient to meet its daily requirements. The price paid by H&H in settlement for silver contained in unrefined silver-bearing materials submitted to them for refining is at a discount, currently 2¢ from the published price, eff. January 20, 1974. (By trade custom, the H&H price for silver in unrefined materials is widely used by smelters and refiners as the basis for making settlement for silver contained in silver-bearing materials and in ores; the discount is in recognition that such silver at the time of purchase is not available in commercial bar form for nearby delivery at New York and is designed to cover carrying, selling, delivery, and other charges involved in marketing of refined silver). **London spot,** pence per tr oz: Quotation is the consensus of London bullion dealers.

(g) **Sterling Exchange:** Noon buying rate as established by Federal Reserve Bank of New York.

(h) **Gold,** dollars per tr oz. **London Final:** Quotation is the second of two settings established daily by consensus of London bullion dealers; purity is 1000 fine. **Engelhard Selling:** The actual price at which Engelhard Industries will sell commercial 400-oz bars of 99.95% gold, as reported daily by the firm.

(i) **London Metal Exchange:** Quotations are official morning session prices on the LME, in pounds sterling per metric ton. Settlement is cash asked. Purities: lead, 99.97%; tin, 99.75% minimum; zinc 98%.

London Metal Exchange Quotations (i)

MAY 1974	COPPER WIREBARS Cash Bid	COPPER WIREBARS Cash Asked	COPPER WIREBARS 3-Month Bid	COPPER WIREBARS 3-Month Asked	LEAD Cash Bid	LEAD Cash Asked	LEAD 3-Month Bid	LEAD 3-Month Asked	ZINC Cash Bid	ZINC Cash Asked	ZINC 3-Month Bid	ZINC 3-Month Asked	TIN Cash Bid	TIN Cash Asked	TIN 3-Month Bid	TIN 3-Month Asked
1	1325.00	1330.00	1259.00	1260.00	305.50	306.00	312.00	313.00	810.00	815.00	765.00	766.00	4005	4010	4000	4002
2	1344.00	1345.00	1267.00	1268.00	307.50	308.50	314.50	315.00	835.00	840.00	781.00	782.00	3970	3975	3983	3985
3	1339.00	1340.00	1276.00	1277.00	315.00	316.00	322.00	322.50	866.00	868.00	795.00	796.00	3960	3965	3980	3985
6	1349.00	1350.00	1285.00	1286.00	316.00	317.00	323.00	323.50	872.00	875.00	801.00	802.00	4010	4015	4030	4035
7	1305.00	1310.00	1249.00	1250.00	304.50	305.50	311.50	312.00	834.00	838.00	774.00	775.00	4035	4045	4040	4045
8	1318.00	1320.00	1263.00	1264.00	307.50	308.00	314.00	314.50	838.00	840.00	777.00	779.00	3995	4000	4020	4025
9	1280.00	1285.00	1248.00	1249.00	304.50	305.00	310.50	311.50	822.00	824.00	774.00	775.00	3985	3990	4008	4012
10	1273.00	1274.00	1233.00	1234.00	299.00	299.50	305.00	305.50	775.00	780.00	751.00	752.00	3920	3930	3945	3950
13	1220.00	1221.00	1183.00	1185.00	284.50	285.00	291.00	291.50	756.00	758.00	717.00	718.00	3880	3885	3905	3910
14	1259.00	1261.00	1210.00	1211.00	293.50	294.00	300.00	300.50	788.00	790.00	744.00	745.00	3935	3940	3970	3972
15	1190.00	1192.00	1149.00	1150.00	272.00	273.00	279.00	279.50	733.00	735.00	699.00	700.00	3885	3890	3905	3907
16	1183.00	1184.00	1148.00	1149.00	277.00	278.00	283.50	284.00	722.00	723.00	696.00	697.00	3884	3885	3912	3915
17	1140.00	1142.00	1110.00	1111.00	268.00	269.00	274.00	275.00	680.00	685.00	656.00	658.00	3900	3905	3930	3940
20	1140.00	1141.00	1100.00	1102.00	268.00	269.00	276.50	277.00	660.00	665.00	626.00	626.50	3900	3910	3945	3950
21	1074.00	1075.00	1039.00	1040.00	243.00	243.50	251.00	252.00	570.00	580.00	535.00	537.00	3740	3750	3780	3785
22	1103.00	1104.00	1070.00	1071.00	246.00	247.00	254.50	255.50	672.00	673.00	616.50	617.50	3795	3800	3830	3835
23	1043.00	1045.00	1015.00	1017.00	237.00	239.00	246.00	247.00	635.00	640.00	580.00	582.00	3735	3740	3760	3770
24	1070.00	1071.00	1040.00	1041.00	254.00	255.00	262.00	262.50	680.00	685.00	636.00	638.00	3770	3780	3795	3800
27	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY	HOLIDAY		HOLIDAY	
28	1089.00	1090.00	1045.00	1046.00	252.50	253.00	260.50	261.00	728.00	730.00	662.00	665.00	3630	3640	3665	3675
29	1015.00	1016.00	985.00	986.00	236.00	236.50	243.50	244.00	580.00	600.00	570.00	575.00	3540	3550	3560	3570
30	1054.00	1056.00	1025.00	1026.00	245.00	245.50	252.50	253.00	654.00	656.00	614.00	616.00	3625	3630	3660	3665
31	1060.00	1061.00	1021.00	1022.00	241.00	241.50	248.00	248.50	640.00	645.00	605.00	607.00	3640	3645	3680	3685
AVG	1190.59		1146.93		276.63		283.70		736.25		650.53		3854.98		3880.02	
SETTLEMENT	1191.50				277.02				738.41				3858.18			

FIGURE 10-5. — Engineering and Mining Journal Markets (Continued).

MARKETS

Metals

(Continued from p 60)

Indium: tr oz 99.97%, eff. 5-1-74
ingots, 100-tr-oz lots ... $3.00

Iridium: tr oz, eff. 4-23-74 ... $400-405
dealers ... $800-850

Lithium: Ingot !b 99.9% (c),
1,000 lb ... $8.53-8.75

Magnesium: lb (f.o.b.) 10,000 lb lots eff. 5-1-74
ingot ... 55¢
die casting alloy ... 59¢

Manganese: 99.9%, boxed (a), eff. 3-27-74
Regular ... 38-38.5¢
6%N ... 41.5¢

Mercury: fl, 20+ lots N.Y. ... $294-298

Molybdenum: (a)
Climax oxide, cans ... $1.92

Nickel: lb, eff. 5-15-74
cathode (a) ... $1.62-1.85
sinter-75, point of entry ... $1.49
sinter-90, point of entry ... $1.53
Ferronickel: (a) ... $1.53

Osmium: tr oz., eff. 11-3-69 ... $200-225
dealers ... $140-165

Palladium: tr oz., eff. 5-1-74 ... $150-155
dealers ... $140-144

Platinum: tr oz., eff. 1-28-74 ... $170-175
dealers ... $185-192

Rhenium: powder, lb. eff. 1-21-74 ... $825

Rhodium: tr oz., eff. 2-26-74 ... $310-315
dealers ... $715-740

Ruthenium: tr oz., eff. 2-14-73 ... $60-65
dealers ... $55-60

Selenium: lb. eff. 5-15-74
comm. grade powder ... $18
high purity ... $21

Tantalum: per lb (a) (d) powder ... $30-38
sheet (e) ... $48-78
rod (e) ... $42-60

Tellurium: lb
slab, 150-lb lots ... $9.00

Thalium: lb, 25-lb lots ... $7.50

Titanium: lb (b) 500 lb 99.3%
max 115 Brinell ... $1.78
Japanese sponge ... $1.70-1.75

Tungsten: lb 98.8% (b)
1,000-lb lots ... $4.50
Hydrogen red 99.99% ... $4.97-6.74

Zirconium: lb (a) sponge, powder platelets:
low hafnium ... $7-14
comm. ... $5-10

Ores & Concentrates

Tons of 2000 lb. or units of 20 lb. unless otherwise stated. Short ton unit=stu; long ton unit=ltu. (a) c.i.f. U.S. ports, (b) f.o.b. ship pt, (c) f.o.b. mine or mill, (g) depending on grade, (i) import duty extra, (n) nominal, (t) term contracts.

Antimony Ore: lump
Mtu 60% ... $29.76-30.86
Stu equivalent ... $27-28

Beryl Ore: stu BeO. 10-12%
imported (a) ... $30

Chrome Ore: lt, dry basis, subject to penalties if guarantees are not met, f.o.b. cars, Atlantic ports; term contracts (subject to negotiation) are generally lower.
Transvaal
44%Cr_2O_3, no ratio ... $37-42
Turkish
48% Cr_2O_3, 3:1 ... $50
Russian, mt, f.o.b. loading point
54-56% Cr_2O_3, 4-1 ratio (pricing basis 48% Cr_2O_3, 4-1 ratio) ... $53-58

Columbite Ore: lb pentoxide, 65% Cb_2O_5 and Ta_2O_5 (a)
spot, 10-1 ratio ... $1.35-1.45

Iron Ore: lt, lower lake ports, eff. 5-1-74
Lake Superior ore
Bessemer
Mesabi 51½% Fe ... $14.00
Old Range ... $14.25
Non-Bessemer
Mesabi 51½% Fe. ... $13.85
Old Range ... $14.10
Taconite pellets (ltu) ... 35.5¢

Manganese Ore (a) (i) ltu
Min. 48% Mn. (low impurities) ... $1.05-1.15
Prices vary depending on impurities.

Molybdenum Concentrates: lb cont Mo., 95% MoS_2 (b); eff. 3-1-74
Climax, cost of container extra ... $1.87
Producer, byproduct,
depending on grade ... $1.60-1.80

Tantalum Ore: lb
Spot tantalite, (c), (d), (e) ... $11.00-12.00
Tanco tantalite ... (n) $10.00
Thailand tin slags ... $5.00

Titanium Ore: ilmenite, lt
TiO_2 54%, f.o.b. cars, Atlantic ports ... $38
Rutile, 96%, st, for del. within 12 mos. ... $330
Slag, lt, 70% f.o.b. ... $60

Tungsten Ore: stu Wo_3, 65% min.
GSA, ex-duty
Domestic ... $74.688
Export ... $81.020

Vanadium Pentoxide: lb V_2O_5 cont. (c)
98% fused eff. 3-1-74 ... $1.75
air dried, (technical) eff. 4-1-71 ... $2.21
dealer (export) ... $1.50

Ferroalloys

(a) carload lots; (b) delivered; (c) lump, bulk; (d) f.o.b. shipping point; (n) nominal.

Ferrochrome: lb contained Cr; (a) (c) (d), eff. 3-27-74
High carbon (67-70% Cr) ... 32¢
Low carbon
67-73% Cr; 0.025% C ... 50¢

Ferrocolumbium: lb contained Cb; (b), ton lots
low alloy, standard grades ... $3.20
high purity (inc. Ni) ... $5.29-6.69

Ferromanganese: lt (a), (c), (d), eff. 5-03-73
Standard 74-76% (Mn) ... $194.50
Imported, del. Pittsburgh, lt ... $350-360

Ferromolybdenum: lb Mo;
lots 5000 lb or more (d)
powdered, packed ... $2.45

Ferrosilicon: lb contained Si; (a) (d) (c); eff. 3-27-74
50% Si ... 21.5¢

Ferrotitanium: low C, lb cont. Ti(b) ... $1.35

Ferrotungsten: lb W (b), eff. 1-2-71
Low-molybdenum ... $4.60

Ferrovanadium: lb V, packed; (d); eff. 6-1-74
Standard ... $4.62
'Carvan' domestic ... $3.99
'Ferovan' ... $3.96

Silicomanganese: lb; (a), (c), (d), eff. 3-27-74
18½-21% Si, 1½% C ... 14.75¢

Spiegeleisen: (d) ltu, Standard
19-23% Mn ... $110-115

Nonmetallic Minerals

Prices received vary and depend upon the characteristics of the commodity. Hence quotations can serve only as general guide to the prices obtained by producers and dealers for their product. st–short ton, lt–long ton, (a) c.i.f. US ports, (b) f.o.b. shipping point, (c) f.o.b. mine or mill, (d)carload lots, (e) depending on grade, (f) f.o.b. vessel, (g) f.o.b. pt. of origin, US port, (n) nominal.

Asbestos: (c), st

Quebec, Canadian Funds

3R	$605	5R	$192
3T	$550	6D	$140
3Z	$512	7M	$65
4T	$283	7R	$60.50
5D	$226	8P	$38
5K	$226		

North Vancouver, BC, Canadian Funds

AAA	$895	AX	$219
AA	$711	AY	$155
A	$541	AZ	$114
AC	$388	CP	$261
AK	$276	CT	$235
AS	$240	CY	$155

Morrisville, Vt. US $

3Z	$424.00	5D	$196.00	7M	$59.00
4A	$393.00	5R	$167.00	7R	$56.00
4K	$260.00	6D	$121.00		
4T	$231.00	7D	$106.00		

Barytes: unground, st
Chemical and glass grade:
Hand picked, 95% $BaSO_4$
Not over 1% Fe, (b), (d) ... $29.50-31.80
Magnetic or flotation, 96% $BaSO_4$
Not over 0.5% Fe. (b) (d) ... $34.50

(Continued on p 70)

FIGURE 10-5. — Engineering and Mining Journal Markets (Continued).

MARKETS

(Continued from p 66)

Imported drilling mud grade, specific gravity 4.20-4.30:
- c.i.f. Gulf ports $17-21
- c.i.f. Canada $15

Ground, st
- Water, 99½% $BaSO_4$
  - 325 mesh, 50-lb bags, (b), (d) $60-80
- Dry ground drilling mud grade, 83-93% $BaSO_4$
  - 3-12% Fe, specific gravity 4.20-4.30,(b), (d) $40-47
- Imported
  - 4.20-4.30 specific gravity (b) $31

Bauxite: lt, (d)
- Imported Guyana refractory grade, super calcined
  - f.o.b. Baltimore, Md. $62.50
  - f.o.b. Mobile, Ala $62.53

Borax: bulk, (d) st, (b) eff. 4-1-73
- Technical, 99½% $59.50
- Dehydrated, min. 99% $109.50
- Sodium Borate concentrates,
  - 46% B_3O_3 .... $63.50
  - 65% B_2O_3 .... $91.00

Corundum: st crude, c.i.f. US ports,
- crystal $120-130
- Boulder $70-75

Feldspar: st, (c), (d), (e) bulk
- North Carolina
  - 40 mesh, flotation $14-21
  - 20 mesh, flotation $13.00
  - 200 mesh, flotation $22.50-27.00
  - 325 mesh, flotation $27.00
- Georgia
  - 200 mesh $28.50
  - 325 mesh $26.50
  - 40 mesh, granular $24.00
- Connecticut
  - 200 mesh $24.50
  - 325 mesh $24.50
  - 20 mesh granular $17.50

Fluorspar: net ton; f.o.b. Ill., Ky.; CaF_2 content, bulk
- Metallurgical:
  - Pellets 70% effective CaF_2 .... $65.50
- Ceramic: calcite and silica variable, CaF_2
  - 88-90% $77.00-83.00
  - 95-96% $82.00-90.00
  - 97% $87.00-96.00
  - In 100-lb paper bag, extra $6
- Acid, dry basis, 97% CaF_2
  - Carloads $78.50-96.00
  - Bags, extra $6
  - Pellets, 88% effective $76.50
  - Wet Filter cake, 8-10% moisture, sold dry content .... subtract approx. $2.50
  - Dry acid concentrates, f.o.b. Wilmington, 97% CaF_2, st $97.50
  - European wet filter cake, 8-10% moisture, sold dry content, duty pd, st, c.i.f. Wilmington/Philadelphia term contracts $95-97
- Mexican: st, f.o.b., metallurgical, effective CaF_2
  - 70% Tampico, f.o.b. vessel $50
  - Mexican border, f.o.b. cars $48.50
  - Acid 97% +, Eagle Pass, bulk, st $60-62

Graphite (natural): f.o.b. source, mt
- Flake and crystalline graphite, bags,
  - Madagascar $175-525
  - Norwegian $120-200
  - German $225-1,300
  - Ceylon $200-350
- Amorphous, non-flake— cryptocrystalline f.o.b. source (80-85%C):
  - Mexican, bulk $24
  - Korean, bags $30

Kyanite: st, (b),
- Georgia, raw, bagged
  - 35 mesh $58
  - 48 mesh $62
  - 100 mesh $65
  - 200 mesh $73
  - 325 mesh .... (n)
- Bulk shipments $2 less per ton

Magnesite: st, f.o.b. Luning, Nev., dead burned grain, bulk $63.50
- Bags $70.50
- f.o.b. Port Joe, Fla., bulk $100

Ochre: st, (c), (d), Georgia
- 50-lb bags, #548 dark buff $50
- 50-lb bags, #404 light buff $60

Phosphate rock: central Florida, land pebble, R.O.M., washed, dried, unground bulk, st, f.o.b. mine
- 66-68% $10.00
- 70-72% $11.75
- 68-70% $10.95
- 74-75% $13.75

Potash: stu K_2O contained, bulk, muriate, 62% K_2O

f.o.b. Carlsbad, N.M. and Moab, Utah, eff. 2-1-74 through 6-30-74
- Standard .... 47¢
- Soluble 62-63% .... 50¢
- Coarse .... 50¢
- Granular .... 52¢

f.o.b. Saskatchewan, Canada, eff. 2-1-74 through 6-30-74
- Standard .... 46-47¢
- Soluble 62-63% .... 50¢
- Coarse .... 50¢
- Granular .... 52¢

Charge for bags on above about $10.00 per ton for muriate

f.o.b. Trona, Calif., year-round, eff. 1-1-74
- Standard .... 59¢
- Fine standard .... 61¢
- Coarse .... 63¢

f.o.b. Tampa, Fla., warehouse (domestic), eff. 7-1-71
- Muriate
  - Standard, 60% K_2O .... 64¢
  - Coarse, 60% K_2O .... 70¢
- Sulfate, bulk, per unit K_2O .... (n)

Pyrites: f.o.b. Climax, Colo., st, bulk 50-52% sulfur $4-5

Quartz rock crystals:
- For fusing, all sizes, st $330-1,100
- Prisms for piezo-electrical and optical use, according to size and grade, lb $2.50-50

Silica: amorphous, 50-lb paper bags, st f.o.b. Elco, Ill.,
- through 200 mesh
  - 90-95% $27
  - 96-99% $28
- through 325 mesh
  - 90-95% $29
  - 98-99.4% $32.50
  - 96-98% $31.50
  - 99.5% $46.50
  - 99.9% passing 400 mesh $68.00
  - 99% below 15 microns $75.00
  - 99% below 10 microns $95.00
- f.o.b. Dierks, Ark., st, 100-lb paper bags
  - 200 mesh $30
  - 325 mesh $40

Sulphur: Following quotes are term contracts.
- US producers, f.o.b. vessel at Gulf ports, La. and Tex., lt.
  - bright $40.00
  - dark $39.00
- Export (Sulexco) f.o.b. Gulf ports:
  - bright $36-37
  - dark $35-36
- Mexican export, f.o.b. vessel, lt, eff. 8-1-70
  - bright $26
  - dark $25

Talc: st (d), (c) containers included unless otherwise specified:
- New Jersey: mineral pulp, ground (bags extra) $10.50-12.50
- Vermont: 98% through 325 mesh, bulk $20
  - 99.99% through 325 mesh, dry processed, bags $58
  - 99.99% through 325 mesh, water beneficiated, bags $86
- New York: 96% through 200 mesh $28.00
  - 99.9% through 325 mesh $44.50
  - 100% through 325 mesh (fluid energy ground) $80-90
- California
  - Standard $37-55.50
  - Fractionated $37-71
  - Micronized $62-104
  - Cosmetic/steatite $44-65
- Georgia:
  - 98-200 .... $14
  - 99-325 .... $25
  - 100-325 (fluid energy ground) $75

Tripoli: lb, paper bags, carloads
- White, f.o.b. Elco, Ill.:
  - Air floated through 200 mesh .... 1.35¢
- Rose and cream, f.o.b. Seneca, Mo. and Rogers, Ark.:
  - Once ground .... 2.90¢
  - Double ground .... 2.90¢
  - Air float .... 3.15¢

Vermiculite: st, (c)
- Montana, So. Carolina $25-38
- South Africa, crude, c.i.f. Atlantic ports $55-70

FIGURE 10-5. — Engineering and Mining Journal Markets (Continued).

METALS WEEK Daily Prices

WEEK ENDING JULY 26, 1974

COPPER

Date	COMEX 1ST POS(C) ¢/LB	COMEX 2ND POS(C)	COMEX 3RD POS(C)
7-22-74	84.200#	85.600	86.600
7-23-74	84.200	84.700	85.600
7-24-74	86.200	86.700	87.500
7-25-74	89.700	89.800	90.000
7-26-74	90.500	90.600	90.800
WEEK AVG	86.9600	87.4800	88.1000

Date	LME CATHODE CASH £/MT	LME CATHODE THR-MO	LME WIREBAR CASH	LME WIREBAR THR-MO
7-22-74	762.000/ 764.000	772.000/ 773.000	773.000/ 774.000	794.000/ 795.000
7-23-74	754.000/ 755.000	766.000/ 768.000	767.000/ 768.000	788.000/ 789.000
7-24-74	769.500/ 770.000	780.000/ 782.000	778.000/ 780.000	798.000/ 799.000
7-25-74	779.000/ 780.000	791.000/ 793.000	796.000/ 797.000	814.000/ 815.000
7-26-74	806.000/ 807.000	822.000/ 824.000	822.000/ 823.000	842.000/ 843.000
WEEK AVG	774.6500	787.1000	787.8000	807.7000

Date	MW ATL SEABOARD ¢/LB	MW CIF EUROPE	MW US PRODUCER DEL	MW US PRODUCER REF
7-22-74	80.722	83.962	86.596	85.971
7-23-74	80.019	83.259	86.596	85.971
7-24-74	81.461	84.701	86.596	85.971
7-25-74	83.180	86.421	86.596	85.971
7-26-74	86.067	89.307	86.596	85.971
WEEK AVG	82.2898	85.5300	86.5960	85.9710

LEAD

Date	LME CASH £/MT	LME THR-MO	MW US PRODUCER ¢/LB
7-22-74	227.000/ 228.000	224.000/ 225.000	24.500
7-23-74	228.000/ 229.500	225.000/ 226.000	24.500
7-24-74	232.000/ 233.000	227.000/ 228.000	24.500
7-25-74	236.000/ 238.000	232.000/ 233.000	24.500
7-26-74	244.000/ 244.500	238.000/ 238.500	24.500
WEEK AVG	234.0000	229.6500	24.5000

TIN

Date	LME CASH £/MT	LME THR-MO	NY MARKET ¢/LB	PENANG MARKET
7-22-74	3490.000/3500.000	3500.000/3510.000	417.750	384.221
7-23-74	3480.000/3500.000	3470.000/3475.000	421.500	379.516
7-24-74	3600.000/3610.000	3590.000/3600.000	431.000	385.789
7-25-74	3670.000/3680.000	3655.000/3660.000	429.500	385.789
7-26-74	3690.000/3700.000	3665.000/3770.000	429.000	390.494
WEEK AVG	3592.0000	3589.5000	425.7500	385.1618

ZINC

Date	LME CASH £/MT	LME THR-MO	MW US PW ¢/LB
7-22-74	447.000/ 448.000	448.000/ 449.000	37.744
7-23-74	456.000/ 457.000	458.000/ 460.000	37.477
7-24-74	475.000/ 476.000	477.000/ 478.000	37.788
7-25-74	477.000/ 479.000	482.000/ 483.000	38.070
7-26-74	491.000/ 493.000	494.000/ 495.000	37.199
WEEK AVG	469.9000	472.4000	37.6556

GOLD

Date	ENGELHARD BUYING $/TR OZ	ENGELHARD SELLING	HANDY & HARMAN NY	LONDON FINAL	LONDON INITIAL
7-22-74	---NA--	143.500	143.300	143.000	144.000
7-23-74	---NA--	144.500	144.250	144.000	141.500
7-24-74	---NA--	144.750	144.550	144.250	142.750
7-25-74	---NA--	149.500	149.300	149.000	144.500
7-26-74	---NA--	149.500	149.300	149.000	149.000
WEEK AVG	-	146.3500	146.1400	145.8500	144.3500

PALLADIUM

Date	MERC EX NEARBY $/TR OZ
7-22-74	141.000/ 145.400
7-23-74	- / 146.000
7-24-74	- / 145.000
7-25-74	- / 147.000
7-26-74	/ 147.500
WEEK AVG	145.7400

PLATINUM

Date	MERC EX 1ST POS(M) $/TR OZ	MERC EX 2ND POS(M)
7-22-74	192.800/ 193.000	214.000/ 214.500
7-23-74	200.900/ 201.000	221.800/ 222.000
7-24-74	211.000/ -	232.000/ -
7-25-74	220.000/ 220.200	241.800/ 242.000
7-26-74	218.900/ 219.000	240.000/ 240.500
WEEK AVG	208.7800	230.0600

SILVER

Date	COMEX 1ST POS(C) ¢/TR OZ	COMEX 2ND POS(C)	COMEX 3RD POS(C)	COMEX 4TH POS(C)	HANDY & HARMAN NY
7-22-74	451.000	470.800	481.100	498.700	425.000
7-23-74	454.500	475.000	485.800	504.100	457.000
7-24-74	472.700	493.000	504.000	522.600	470.000
7-25-74	492.500	513.000	524.000	542.600	487.500
7-26-74	489.600#	510.000	521.500	540.900	483.000
WEEK AVG	472.0600	492.3600	503.2800	521.7800	464.5000

Date	LME CASH PENCE/TR OZ	LME SEVEN-MO	LONDON SPOT	LONDON SPOT/US EQV ¢/TR OZ	MW US PRODUCER
7-22-74	173.500/ 174.500	185.500/ 186.500	175.000	418.513	425.229
7-23-74	184.500/ 185.500	194.500/ 196.500	183.500	438.565	457.246
7-24-74	188.000/ 190.000	201.500/ 203.000	186.500	446.481	470.211
7-25-74	198.500/ 200.500	214.000/ 215.000	197.500	472.124	487.726
7-26-74	195.500/ 196.500	211.000/ 212.000	196.500	470.087	483.187
WEEK AVG	188.7000	201.9500	187.8000	449.1540	464.7198

MERCURY

Date	COMEX 1ST POS(C) $/FL	COMEX 2ND POS(C)
7-22-74	290.000	305.000
7-23-74	290.000	305.000
7-24-74	290.000	305.000
7-25-74	290.000	305.000
7-26-74	290.000#	305.000
WEEK AVG	290.0000	305.0000

FOREIGN EXCHANGE RATES

Date	£	DM	¥
7-22-74	2.39150	.392500	.003433
7-23-74	2.39000	.393300	.003416
7-24-74	2.39400	.398800	.003415
7-25-74	2.39050	.392000	.003402
7-26-74	2.39230	.390300	.003385
WEEK AVG	2.39166	.393380	.003410

LEAD, ZINC AND SILVER SALES IN THE US LAST WEEK: LEAD 12381 TONS, ZINC 12100 TONS, SILVER 686290 TR OZ

The lead and zinc tonnages include average price sales and price-date-of-shipment sales not used to compute the respective METALS WEEK producer prices, as well as all flat price sales reported to METALS WEEK. The silver volume includes only sales necessary to compute the METALS WEEK producer price.

PENANG TIN PRICES ARE CONVERTED FROM MALAYSIAN DOLLARS/PICUL TO US CENTS/LB USING THE FIRST NATIONAL CITY BANK NY SELLING RATES FOR EACH DAY:

7-22-74	.4182
7-23-74	.4182
7-24-74	.4182
7-25-74	.4182
7-26-74	.4182

Note: The weekly average of daily bid and asked quotations is the mean of the two prices.

The London Spot/US Equivalent silver price is computed by METALS WEEK using the official noon buying rate for sterling as quoted daily by the NYFRB.

Comex (C) Mercantile Exchange (M) positions for this week are as follows:

	1st position	2nd position	3rd position	4th position
(C) Copper	July-Sept. 1974	Dec. 1974	July 1975	—
(C) Mercury	July 1974	Sept. 1975	—	—
(C) Silver	July 1974	Dec. 1974	Mar. 1975	Sept. 1975
(M) Platinum	Oct. 1974	Oct. 1975	—	—

# indicates last day of trading month

FIGURE 10-6. — Metals Week Price Quotations.

METALS WEEK Weekly Prices

MAJOR METALS					
ALUMINUM		¢/LB	£/MT	DM/100 KG	¥/MT
MAJOR US PRODUCER	6-03-74	33.500	308.948	188.403	217090
MW US MARKET	7-29-74	49.000-	451.895-	275.575-	317535-
		51.000	470.339	286.823	330496
COPPER					
COMEX 1ST POS(C)	WEEK AVG	86.960	801.586	487.346	562205
COMEX 2ND POS(C)	WEEK AVG	87.480	806.379	490.260	565567
COMEX 3RD POS(C)	WEEK AVG	88.100	812.094	493.734	569576
LME CATHODE CASH	WEEK AVG	84.038	774.650	470.969	543314
LME CATHODE THR-MO	WEEK AVG	85.389	787.100	478.539	552046
LME WIREBAR CASH	WEEK AVG	85.464	787.800	478.964	552537
LME WIREBAR THR-MO	WEEK AVG	87.623	807.700	491.063	566494
MW #2 SCRAP	7-25-74	72.000	664.008	404.927	466582
MW ATL SEABOARD	WEEK AVG	82.290	758.536	461.173	532012
MW CIF EUROPE	WEEK AVG	85.530	788.404	479.332	552960
MW NY DEALER	7-25-74	94.000-	866.900-	528.654-	609149-
		95.000	876.122	534.278	615629
MW US PROD CATH	WEEK AVG	85.000	783.899	478.038	550826
MW US PRODUCER DEL	WEEK AVG	86.596	798.230	485.306	559852
MW US PRODUCER REF	WEEK AVG	85.971	792.469	481.803	555811
PRODUCER CANADA/NA	7-03-74	82.500-	760.843-	463.978-	534625-
		87.800	809.721	493.785	568971
US BRASS INGOT/115	7-19-74	90.000	830.010	506.158	583228
US BRASS INGOT/215	7-19-74	128.000	1180.459	719.869	829479
US PROD CATHODES	6-06-74	85.000	783.899	478.038	550826
US PROD WIREBARS	6-06-74	85.625-	789.663-	481.553-	554876-
		87.000	802.343	489.286	563787
LEAD					
LME CASH	WEEK AVG	25.385	234.000	142.267	164120
LME THR-MO	WEEK AVG	24.914	229.650	139.622	161069
MW SECONDARY PROD	6-17-74	24.500	225.947	137.788	158767
MW US PRODUCER	WEEK AVG	24.500	225.838	137.304	158395
US PRODUCER	6-17-74	24.500	225.947	137.788	158767
US ROLLED SHEET	6-24-74	30.000	276.670	168.719	194409
TIN					
LME CASH	WEEK AVG	389.678	3592.000	2183.853	2519309
LME THR-MO	WEEK AVG	389.407	3589.500	2182.334	2517555
MW NEW YORK	7-25-74	415.000	3827.270	2333.952	2689327
NY MARKET	WEEK AVG	425.750	3924.506	2386.010	2752517
PENANG MARKET	WEEK AVG	385.162	3550.370	2158.543	2490111
ZINC					
EUROPEAN PRODUCER	3-19-74	35.783	330.000	201.241	231883
IMPORTED PW	4-08-74	35.300-	325.549-	198.526-	228755-
		39.500	364.282	222.147	255972
IMPORTED SHG	7-25-74	35.800-	330.160-	201.338-	231995-
		45.000	415.005	253.079	291614
LME CASH	WEEK AVG	50.977	469.900	285.688	329572
LME THR-MO	WEEK AVG	51.248	472.400	287.208	331326
MW US PW	WEEK AVG	37.656	347.104	211.031	243447
US #3 ALLOY	7-25-74	39.500-	364.282-	222.147-	255972-
		72.000	664.008	404.927	466582
US DEALER SHG	7-25-74	62.000-	571.785-	348.687-	401779-
		65.000	599.452	365.559	421220
US HG	7-16-74	38.000	350.449	213.711	246252
US PW	7-16-74	35.000-	322.782-	196.839-	226811-
		40.000	368.894	224.959	259212
US ROLLED PLATE	3-25-74	49.750	458.811	279.793	322395
US ROLLED SHEET	3-25-74	81.000	747.009	455.542	524905
US SHG	7-10-74	36.500-	336.615-	205.275-	236531-
		41.500	382.727	233.395	268933
PRECIOUS METALS					
GOLD		$/TR OZ	£/TR OZ	DM/GM	¥/GM
ENGELHARD BUYING	WEEK AVG	-----------	----NOT	AVAILABLE----	-----------
ENGELHARD SELLING	WEEK AVG	146.350	61.192	11.961	1380
HANDY & HARMAN NY	WEEK AVG	146.140	61.104	11.944	1378
LONDON FINAL	WEEK AVG	145.850	60.983	11.920	1375
LONDON INITIAL	WEEK AVG	144.350	60.356	11.797	1361
IRIDIUM					
MAJOR PRODUCER	4-23-74	400.000-	167.329-	32.806-	3780-
		405.000	169.421	33.216	3827
NY DEALER	7-25-74	800.000-	334.658-	65.612-	7560-
		850.000	355.574	69.713	8033
OSMIUM					
MAJOR PRODUCER	11-03-69	200.000-	83.665-	16.403-	1890-
		225.000	94.123	18.453	2126
NY DEALER	7-25-74	140.000-	58.565-	11.482-	1323-
		165.000	69.023	13.533	1559
PALLADIUM					
MAJOR PRODUCER	5-01-74	150.000-	62.748-	12.302-	1418-
		155.000	64.840	12.712	1465
MERC EX NEARBY	WEEK AVG	145.740	60.937	11.911	1374
NY DEALER	7-25-74	142.000-	59.402-	11.646-	1342-
		145.000	60.657	11.892	1370
PLATINUM					
MAJOR PRODUCER	6-03-74	190.000-	79.481-	15.583-	1796-
		200.000	83.665	16.403	1890
MERC EX 1ST POS(M)	WEEK AVG	208.780	87.295	17.063	1968
MERC EX 2ND POS(M)	WEEK AVG	230.060	96.193	18.802	2169
NY DEALER	7-25-74	207.000-	86.593-	16.977-	1956-
		212.000	88.684	17.387	2003
RHODIUM					
MAJOR PRODUCER	6-03-74	350.000-	146.413-	28.705-	3308-
		360.000	150.596	29.526	3402
NY DEALER	7-25-74	700.000-	292.826-	57.411-	6615-
		725.000	303.284	59.461	6851
RUTHENIUM					
MAJOR PRODUCER	2-14-73	60.000-	25.099-	4.921-	567-
		65.000	27.191	5.331	614
NY DEALER	7-25-74	55.000-	23.008-	4.511-	520-
		60.000	25.099	4.921	567
SILVER		¢/TR OZ	P/TR OZ	DM/KG	¥/KG
COMEX 1ST POS(C)	WEEK AVG	472.060	197.378	385.803	44507
COMEX 2ND POS(C)	WEEK AVG	492.360	205.865	402.394	46420
COMEX 3RD POS(C)	WEEK AVG	503.280	210.431	411.319	47450
COMEX 4TH POS(C)	WEEK AVG	521.780	218.166	426.438	49194
HANDY & HARMAN NY	WEEK AVG	464.500	194.217	379.625	43794
LME CASH	WEEK AVG	451.306	188.700	368.842	42550
LME SEVEN-MO	WEEK AVG	482.996	201.950	394.741	45538
LONDON SPOT	WEEK AVG	449.154	187.800	367.083	42347
MW US PRODUCER	WEEK AVG	464.720	194.308	379.804	43814
MINOR METALS					
ANTIMONY		¢/LB	£/MT	DM/100 KG	¥/MT
LONE STAR/LAREDO	6-17-74	265.000	2443.920	1490.355	1717281
LONE STAR/NY	6-17-74	267.000	2462.364	1501.603	1730242
NY DEALER	7-25-74	290.000-	2674.478-	1630.954-	1879289-
		295.000	2720.590	1659.074	1911690
		$/STU	£/MTU	DM/MTU	¥/MTU
NY DEALER ORE	7-25-74	36.370-	16.771-	102.272-	11784-
		37.480	17.283	105.393	12144
ORE/STU EQUIV	7-25-74	33.000-	15.217-	92.796-	10693-
		34.000	15.678	95.608	11017
		¢/LB	£/MT	DM/100 KG	¥/MT
RMM/LAREDO	6-17-74	223.000	2056.581	1254.147	1445108
RMM/NY	6-17-74	225.000	2075.026	1265.395	1458069
TRIOXIDE	7-15-74	166.000-	1530.908-	933.581-	1075731-
		205.000	1890.579	1152.916	1328463
ARSENIC					
TRIOXIDE/LAREDO	6-03-74	10.500	96.835	59.052	68043
TRIOXIDE/NY	7-25-74	13.000	119.890	73.112	84244
BISMUTH		$/LB	£/KG	DM/100 KG	¥/MT
MAJOR PRODUCER	6-17-74	9.000-	8.300-	5061.582-	5832275-
		12.000	11.067	6748.776	7776367
CADMIUM		$/LB	£/LB	DM/100 KG	¥/MT
US PRODUCER	5-07-74	4.250-	1.778-	2390.191-	2754130-
		4.300	1.799	2418.311	2786531
GALLIUM		$/GM	£/GM	DM/GM	¥/GM
MAJOR PRODUCER	7-25-74	.800	.335	2.041	235
NY DEALER	7-25-74	.700	.293	1.786	206
GERMANIUM		$/KG	£/KG	DM/KG	¥/KG
NY DEALER	2-01-74	275.000	115.039	701.531	80835
NY DEALER DIOXIDE	2-01-74	145.500	60.866	371.173	42769
US DIOXIDE	6-08-70	167.500	70.069	427.296	49236
US PRODUCER	6-08-70	293.000	122.569	747.449	86126
INDIUM		¢/TR OZ	P/TR OZ	DM/KG	¥/KG
US INGOTS	7-25-74	5.500	2.301	4.511	520
MERCURY		$/FL	£/FL	DM/FL	¥/FL
COMEX 1ST POS(C)	WEEK AVG	290.000	121.255	737.201	85044
COMEX 2ND POS(C)	WEEK AVG	305.000	127.526	775.332	89443
LMB EUROPE	7-25-74	285.000-	119.222-	727.041-	83774-
		295.000	123.405	752.551	86714
MW NEW YORK	7-25-74	305.000-	127.588-	778.061-	89653-
		317.000	132.608	808.673	93180
RHENIUM		$/LB	£/LB	DM/100 KG	¥/MT
US PERRHENIC ACID	6-24-74	625.000	261.452	35149.872	4050191
US PRODUCER POWDER	6-24-74	675.000	282.368	37961.862	4374206
SELENIUM					
MAJ PROD/COMML	5-15-74	18.000	7.530	10123.163	11664550
MAJ PROD/HI-PURITY	5-13-74	21.000	8.785	11810.357	13608642
TELLURIUM					
MAJ PROD SLAB	5-06-74	9.000	3.765	5061.582	5832275
THALLIUM					
MAJOR PRODUCER	7-25-74	7.500	3.137	4217.985	4860229
ZIRCONIUM		$/ST	£/MT	DM/100 KG	¥/MT
ORE/AUSTRALIAN	6-26-74	550.000-	253.614-	1546.594-	178208-
		575.000	265.142	1616.894	186309
ORE/US	6-26-74	95.000	43.806	267.139	30781
		$/LB	£/MT	DM/100 KG	¥/MT
US BILLET/BAR	6-01-70	8.000-	7377.871-	4499.184-	5184245-
		11.000	10144.572	6186.378	7128336
US SHEET/STRIP	6-01-70	12.000-	11066.806-	6748.776-	7776367-
		17.000	15677.975	9560.765	11016520
US SPONGE	6-01-70	5.500-	5072.286-	3093.189-	3564168-
		7.000	6455.637	3936.786	4536214
FERROALLOYS					
CALCIUM		¢/LB	£/MT	DM/100 KG	¥/MT
CALCIUM-MN-SI	1-02-71	38.500	355.060	216.523	249492
CALCIUM-SILICON	7-22-74	57.000	525.673	320.567	369377
METAL CROWNS	7-25-74	95.000	876.122	534.278	615629
CHROME		$/MT	£/MT	DM/100 KG	¥/MT
RUSSIAN ORE	3-01-74	53.000-	22.171-	13.520-	15579-
		58.000	24.263	14.796	17049
		$/LT	£/MT	DM/100 KG	¥/MT
TRANSVAAL ORE	3-25-74	37.000-	15.233-	9.290-	10704-
		44.000	18.115	11.047	12729
TURKISH ORE	1-01-74	50.000	20.586	12.554	14465
		$/LB	£/LB	DM/100 KG	¥/MT
US ALMNOTHRMIC MTL	7-29-74	2.030	.849	1141.668	1315502
US ELECTRLTC METAL	7-01-74	1.780	.745	1001.068	1153494
US METAL(9% CARBN)	7-01-74	1.900	.795	1068.556	1231258
US VACUUM MTL PLTS	7-29-74	1.850-	.774-	1040.436-	1198857-
		2.100	.878	1181.036	1360864
COBALT		$/LB	£/KG	DM/KG	¥/KG
CERAMIC OXIDE/70%	7-08-74	3.630	3.348	20.415	2352
CERAMIC OXIDE/72%	7-08-74	3.740	3.449	21.034	2424
FINE POWDER/125 KG	7-08-74	6.610	6.096	37.175	4283
FINE POWDER/5 KG	7-08-74	6.960	6.419	39.143	4510
FINE POWDER/50 KG	7-08-74	6.650	6.133	37.399	4309
METALLURGICL OXIDE	7-08-74	3.840	3.541	21.596	2488
POWDER	7-08-74	5.070	4.676	28.514	3286
S-GRADE POWDER	7-15-74	4.000	3.689	22.496	2592
SHOT/CATHDE/250 KG	7-08-74	3.750	3.458	21.090	2430
SHOT/CATHODE/50 KG	7-08-74	3.800	3.504	21.371	2463
SHOT/SM QUANTITIES	7-08-74	3.850	3.551	21.652	2495
COLUMBIUM		¢/LB	£/MT	DM/100 KG	¥/MT
BRAZIL PYROCHLORE	3-08-73	142.000	1309.572	798.605	920203
CANADA PYROCHLORE	5-29-74	160.160	1477.050	900.737	1037886
SPOT COLUMBITE ORE	7-05-74	160.000-	1475.574-	899.837-	1036849-
		170.000	1567.798	956.077	1101652
		$/LB	£/LB	DM/100 KG	¥/MT
US METALLGCL INGOT	2-15-67	16.000-	6.693-	8998.367-	10368489-
		27.000	11.295	15184.745	17496826

FIGURE 10-6. — Metals Week Price Quotations (Continued).

WEEK ENDING JULY 26, 1974

US METALLGCL POWDR	2-15-67	11.000-	4.602-	6186.378-	7128336-
		22.000	9.203	12372.755	14256673
US REACTOR INGOT	2-15-67	17.500-	7.321-	9841.964-	11340535-
		28.000	11.713	15747.143	18144856
US REACTOR POWDER	2-15-67	12.000-	5.020-	6748.776-	7776367-
		23.000	9.621	12935.153	14904703
FERROCHROME		¢/LB	£/LB	DM/100 KG	¥/MT
US BLOCKING(HI-SI)	1-02-71	28.600	.120	160.846	185337
US BLOCKING(LO-SI)	1-02-71	27.600	.115	155.222	178856
US CHARGE CHROME	7-22-74	37.000	.155	208.087	239771
		¢/LB	£/MT	DM/100 KG	¥/MT
US CHROMSOL	7-22-74	27.400	252.692	154.097	177560
		¢/LB	£/LB	DM/100 KG	¥/MT
US HIGH-CARBON	7-22-74	41.000	.172	230.583	265693
US IMPORTED CHARGE	7-25-74	50.000-	.209-	281.199-	324015-
		55.000	.230	309.319	356417
US IMPRT LO-C/.05%	7-25-74	80.000-	.335-	449.918-	518424-
		85.000	.356	478.038	550826
US IMPT LO-C/.025%	7-25-74	85.000-	.356-	478.038-	550826-
		90.000	.376	506.158	583228
		¢/LB	£/MT	DM/100 KG	¥/MT
US LOW-CARBON/.025	7-22-74	70.000	645.564	393.679	453621
		¢/LB	£/LB	DM/100 KG	¥/MT
US LOW-CARBON/.05%	7-22-74	60.000	.251	337.439	388818
US SIMPLEX(LOW-C)	7-22-74	60.000	.251	337.439	388818
FERROCOLUMBIUM		$/LB	£/MT	DM/100 KG	¥/MT
SPOT/LOW-ALLOY	7-01-74	3.650	3366.154	2052.753	2365312
US HI-PURITY	4-03-74	5.290-	4878.617-	2975.085-	3428082-
		6.690	6169.744	3762.442	4335325
FERROMANGANESE		¢/LB	£/LB	DM/100 KG	¥/MT
US "MS" MANGANESE	7-22-74	32.000	.134	179.967	207370
US FERROMN-SILICON	7-22-74	28.000	.117	157.471	181449
US LO-CARBON/.1%C	7-22-74	48.000	.201	269.951	311055
US LO-CARBON/.30%C	7-22-74	47.000	.197	264.327	304574
US LO-CARBON/.75%C	7-22-74	48.000	.201	269.951	311055
		¢/LB	£/MT	DM/100 KG	¥/MT
US MN-NITRIDE/HISI	7-22-74	37.500	345.838	210.899	243011
US MN-NITRIDE/LOSI	3-27-74	34.500	318.171	194.027	223571
		$/LT	£/MT	DM/100 KG	¥/MT
US STANDARD LO-PHO	7-22-74	385.000	158.510	96.663	111381
US STANDARD/74-76%	3-27-74	---	---	---	---
US STANDARD/78%MN	7-22-74	350.000	144.100	87.875	101255
US STANDRD:IMPORTD	7-18-74	400.000-	164.685-	100.429-	115720-
		410.000	168.802	102.939	118613
		¢/LB	£/LB	DM/100 KG	¥/MT
US/MED CAR IMPORT	7-18-74	34.000-	.142-	191.215-	220330-
		36.000	.151	202.463	233291
US/MEDIUM CARBON	7-22-74	30.500	.128	171.531	197649
FERROMOLYBDENUM		$/LB	£/LB	DM/100 KG	¥/MT
CLIMAX LUMP	7-01-74	2.600	1.088	1462.235	1684879
CLIMAX POWDER	7-01-74	2.660	1.113	1495.979	1723761
DEALER EXPORT	3-25-74	2.350-	.983-	1321.635-	1522872-
		2.450	1.025	1377.875	1587675
FERROPHOSPHOROUS		$/LT	£/MT	DM/100 KG	¥/MT
23-24% PHOSPHOROUS	1-01-74	150.000	61.757	37.661	43395
FERROSILICON		¢/LB	£/MT	DM/100 KG	¥/MT
US REGULAR/50%SI	7-22-74	30.000	276.670	168.719	194409
US/35-40 ZIRCON-SI	7-22-74	51.000	470.339	286.823	330496
US/5% MAGNESIUM	7-22-74	30.000	276.670	168.719	194409
US/9% MAGNESIUM	5-29-74	32.000	295.115	179.967	207370
US/FNDRY/75SI-1%CA	7-22-74	40.500	373.505	227.771	262452
US/IMPORTED/75%SI	7-01-74	90.000-	830.010-	506.158-	583228-
		100.000	922.234	562.398	648031
US/REGULAR/75%SI	7-22-74	38.500	355.060	216.523	249492
US/REGULAR/85%SI	3-27-74	---	---	---	---
US/REGULAR/90%SI	3-27-74	---	---	---	---
FERROTUNGSTEN		$/LB	£/MT	DM/100 KG	¥/MT
DEALER EXPORT	6-20-74	6.000-	5533.403-	3374.388-	3888183-
		7.000	6455.637	3936.786	4536214
US LOW-MOLYBDENUM	6-01-74	5.500	5072.286	3093.189	3564168
FERROVANADIUM		$/LB	£/KG	DM/100 KG	¥/MT
US CARVAN	6-01-74	3.990	3.680	2243.968	2585642
US FEROVAN	7-01-74	4.500	4.150	2530.791	2916138
US STANDARD GRADE	6-01-74	4.620	4.261	2598.279	2993901
IRON ORE		$/LT	£/LT	DM/100 KG	¥/MT
BESS MESABI	6-24-74	14.000-	5.857-	3.515-	4050-
		14.750	6.170	3.703	4267
BESSEMER/OLD RANGE	6-24-74	14.250-	5.961-	3.578-	4123-
		15.000	6.275	3.766	4340
NON-B MESABI	6-24-74	13.850-	5.794-	3.477-	4007-
		14.600	6.108	3.666	4224
NON-B OLD RANGE	6-24-74	14.100-	5.898-	3.540-	4079-
		14.850	6.212	3.728	4296
		¢/LTU	£/MTU	DM/MTU	¥/MTU
TACONITE PELLETS	6-24-74	35.500-	.146-	.891-	103-
		36.300	.149	.911	105
MANGANESE					
ORE (MIN 48% MN)	7-01-74	110.000-	.453-	2.762-	318-
		118.000	.486	2.963	341
		¢/LB	£/MT	DM/100 KG	¥/MT
US METAL/ REGULAR	5-01-74	41.500	382.727	233.395	268933
US METAL/4-5% N	3-10-74	---	---	---	---
US METAL/6% N	5-01-74	44.500	410.394	250.267	288374
		$/ST	£/MT	DM/100 KG	¥/MT
US SPIEGELSN/19-23	4-26-74	110.000-	50.723-	309.319-	35642-
		115.000	53.028	323.379	37262
MOLYBDENUM		$/LB	£/LB	DM/100 KG	¥/MT
BYPRODUCT CONC	7-01-74	1.800-	.753-	1012.316-	1166455-
		2.080	.870	1169.788	1347904
CLIMAX CONCENTRATE	7-01-74	2.050	.858	1152.916	1328463
CLIMAX OXIDE/CANS	7-01-74	2.270	.950	1276.643	1471029
DEALER OXIDE	7-01-74	2.080-	.870-	1169.788-	1347904-
		2.270	.950	1276.643	1471029
K-1 OXIDE/CANS	7-01-74	2.290	.958	1287.891	1483990
K-2 OXIDE/CANS	7-01-74	2.220	.929	1248.523	1438628
NICKEL		$/LB	£/MT	DM/100 KG	¥/MT
MAJ PROD CATHODE	6-28-74	1.850	1706.133	1040.436	1198857
MAJ PROD F-SHOT	6-28-74	1.910	1761.467	1074.180	1237738
MAJ PROD PELLETS	6-28-74	1.850	1706.133	1040.436	1198857

MAJ PROD SINTER 75	6-28-74	1.730	1595.465	972.948	1121093
MAJ PROD SINTER 90	6-28-74	1.770	1632.354	995.444	1147014
NY DEALER CATHODE	7-25-74	2.350-	2167.250-	1321.635-	1522872-
		2.750	2536.143	1546.594	1782084
SLN FERRONI/FN4	5-16-74	1.780	1641.576	1001.068	1153494
US PROD FERRONI	6-07-74	1.810	1669.243	1017.940	1172935
US/NI200 ROD	7-13-74	3.080	2840.480	1732.186	1995934
US/NI200 SHEET	7-13-74	3.260	3006.482	1833.417	2112580
SILICOMANGANESE		¢/LB	£/MT	DM/100 KG	¥/MT
US 1.5% CARBON	3-27-74	14.750	136.029	82.954	95585
US 2% CARBON	7-22-74	18.500	170.613	104.044	119886
US 3% CARBON	7-22-74	18.500	170.613	104.044	119886
		$/LT	£/MT	DM/100 KG	¥/MT
US/12.5-16%SI	3-25-74	303.000	124.749	76.075	87658
SILICON		¢/LB	£/MT	DM/100 KG	¥/MT
DEALER IMPORT	7-11-74	168.000-	1549.353-	944.829-	1088691-
		175.000	1613.909	984.196	1134054
US/.35%FE/.07%CA	7-22-74	59.900	552.418	336.876	388170
US/.5%FE/.07%CA	7-22-74	58.200	536.740	327.316	377154
US/1%FE/.07%CA	7-22-74	55.000	507.229	309.319	356417
US/1.5FE/.03-.4%CA	5-29-74	34.750-	320.476-	195.433-	225191-
		35.500	327.393	199.651	230051
TANTALUM		$/LB	£/LB	DM/KG	¥/KG
SPOT TANTALITE ORE	6-05-74	13.000-	5.438-	73.112-	8424-
		14.000	5.857	78.736	9072
TANCO TANTALITE	4-03-74	---------------NOMINAL---------------			
THAILAND TIN SLAGS	1-01-74	5.000	2.092	28.120	3240
US POWDER	7-01-74	31.000-	12.968-	174.343-	20089-
		41.500	17.360	233.395	26893
US ROD	4-30-74	42.000-	17.570-	235.207-	27217-
		60.000	25.099	337.439	38882
US SHEET	4-30-74	48.000-	20.079-	269.951-	31105-
		78.000	32.629	438.670	50546
TUNGSTEN		$/STU	£/MTU	DM/MTU	¥/MTU
GSA DOMESTIC	7-25-74	89.013	41.045	250.304	28842
GSA EXPORT	7-25-74	90.113	41.553	253.397	29198
		$/STU	£/MTU	DM/MTU	¥/MTU
LMB ORE	7-25-74	91.083-	42.000-	256.125-	29512-
		94.336	43.500	265.272	30566
		$/LB	£/MT	DM/100 KG	¥/MT
US HYDROGN-RED MTL	6-17-74	9.640-	8890.334-	5421.516-	6247015-
		11.340	10458.132	6377.593	7348667
VANADIUM					
US PENTOXIDE/AIR	6-01-74	2.410	2222.584	1355.379	1561754
US PENTOXIDE/FUSED	7-01-74	1.900	1752.244	1068.556	1231258
LIGHT METALS					
BERYLLIUM		$/STU	£/MTU	DM/MTU	¥/MTU
BERYL ORE	3-18-74	30.000	13.834	84.360	9720
		$/LB	£/MT	DM/100 KG	¥/MT
US BE-CU/ALLOY 25	6-13-74	3.880	3578.267	2182.104	2514359
US BE-CU/CAST INGT	6-13-74	2.590	2388.586	1456.611	1678399
US BE-CU/MAST ALLY	5-06-74	59.000	54411.797	33181.480	38233804
US ROD	5-01-74	106.050	97802.900	59642.303	68723643
LITHIUM		¢/LB	£/MT	DM/100 KG	¥/MT
US CARBONATE	5-15-74	64.000-	590.230-	359.935-	414740-
		65.500	604.063	368.371	424460
US CARBONATE PELLT	5-15-74	70.000-	645.564-	393.679-	453621-
		71.500	659.397	402.115	463342
		$/LB	£/MT	DM/100 KG	¥/MT
US INGOT	4-15-74	8.530-	7866.655-	4797.255-	5527701-
		8.750	8069.546	4920.982	5670268
US ROD	4-15-74	15.000	13833.508	8435.969	9720459
MAGNESIUM		¢/LB	£/MT	DM/100 KG	¥/MT
US DIE CAST ALLOY	7-01-74	69.000	636.341	388.055	447141
US PRIMARY INGOT	7-01-74	65.000	599.452	365.559	421220
TITANIUM		$/LT	£/MT	DM/100 KG	¥/MT
ORE/ILMENITE	6-28-74	55.000	22.644	13.809	15912
		$/ST	£/MT	DM/100 KG	¥/MT
ORE/RUTILE	6-28-74	520.000-	239.781-	1462.235-	168488-
		550.000	253.614	1546.594	178208
		$/LT	£/MT	DM/100 KG	¥/MT
SLAG	1-01-74	60.000	24.703	15.064	17358
		$/LB	£/MT	DM/100 KG	¥/MT
SPONGE/JAPANESE	7-01-74	2.000	1844.468	1124.796	1296061
SPONGE/US	7-01-74	1.900	1752.244	1068.556	1231258
US BAR	7-01-74	5.760	5312.067	3239.412	3732656
US BILLET	7-01-74	3.910	3605.934	2198.976	2533800
US PLATE	7-01-74	5.250	4841.728	2952.589	3402161
US SHEET/STRIP	7-01-74	10.210	9416.008	5742.083	6616392

NOTE: All quotes originate in US currency except for 15 prices which originate in British pounds sterling and are converted into US currency. These prices include Zinc, European Producer; Silver, London Spot; and Tungsten, LMB Ore. The remaining 12 prices are the copper, lead, tin, zinc, and silver LME quotes. The 41 daily prices which are averaged on page 8 are converted using the average exchange rates published on page 8; however, daily prices originating in British currency may use an unpublished average conversion rate if there is a variance in the holiday/business day schedule between the US and Britain. All other prices on these pages are converted using the actual exchange rate of the next to the last business day of the week, which is usually Thursday. For a more detailed explanation of METALS WEEK quotations, calculations and conversions, see the Reference Section of the METALS WEEK 1973 PRICE HANDBOOK.

FIGURE 10-6. — Metals Week Price Quotations (Continued).

BURLINGTON NORTHERN INC.

Original
Straight Bill of Lading/Short form
Not Negotiable

RECEIVED, subject to the classifications and tariffs in effect on the date of the issue of this Bill of Lading,

BURLINGTON NORTHERN

Shipper's No. ____________

Agent's No. ____________

SHEET 1

at ____, 19____

from ____

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown), marked, consigned, and destined as indicated below, which said carrier (the word carrier being understood throughout this contract c, meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Official, Southern, Western and Illinois Freight Classifications in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment.

Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, including those on the back thereof, set forth in the classification or tariff which governs the transportation of this shipment, and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns.

(Mail or street address of consignee—For purposes of notification only.)

Consigned to ____

Destination ____________ State of ____________ County of ____________

Delivery Address* ____
(*To be filled in only when shipper desires and governing tariffs provide for delivery thereat.)

Route ____

Delivering Carrier ____________ Car Initial ____________ Car No. ____________

No. Packages	Description of Articles, Special Marks, and Exceptions	*WEIGHT (Subject to Correction)	CLASS OR RATE	CHECK COLUMN

Subject to Section 7 of conditions, of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

____
Signature of consignor.)

If charges are to be prepaid, write or stamp here, "To be Prepaid."

Rec'd $ ____________ to apply in prepayment of the charges on the property described hereon.

____
Agent or Cashier.

Per ____________
(The signature here acknowledges only the amount prepaid.)

Charges advanced:

$ ____________

*If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."

NOTE—Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.

The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding

____________ per ____________

____________ Shipper ____________ Agent

Per ____________ Per ____________

Permanent postoffice address of shipper— ____________

FORM 15217 11-70

PRINTED IN U.S.A.

FIGURE 10-7. — Bill of Lading.

CHAPTER 11 — MINE FINANCING

By

W. A. VINE*

INTRODUCTION

When considering the formation of an organization to conduct a small mining venture, the operators should have a very clear idea of at least two aspects of the financial requirements. One aspect is the amount and time sequence of the financial needs, and the other aspect is the source of money to satisfy the needs.

It is the purpose of this section to consider briefly each of the foregoing two aspects in turn, from the point of view of the small operator who needs this information to help him understand his problems better, and to offer some suggestions about how he may solve them.

COMPOSITION AND PURPOSE OF A BUSINESS

When an individual, or group of individuals, visualizes a venture from which a profit is expected, that vision is the conception of a business. The being, then, is the business. Its substance is made up of men who direct, and other men who labor; machines and materials; and finally, money. The four elements, men, machines, materials, and money are commonly thought of as the four big M's of business. In the case of an existing business, its reason for being is to make a profit; profits are not made unless there is a reasonably well balanced inventory of all four of the elements. This section is concerned with the fourth element, money.

SOME ACCOUNTING FUNDAMENTALS

Certain standard accounting practices and techniques must be known by everyone who would attempt to start a business, not only to know how to account for money for his own sake, but to be able to talk a common language with other individuals, organizations, and the government.

The financial condition of a business at any one time is displayed in a **balance sheet.** A business **owns** and it **owes.** The amount that a business owns is necessarily equal to the amount that it owes; therein lies the balance of the balance sheet.

The business owes to people in two different relationships to it. Creditors are individuals who have no part in the management of the business but have a claim against it because they have provided money, goods, or services for which the business has not paid them. The owners of the business are individuals who have invested money in the business and have a claim on all of the assets of the business that remain after the creditors have been satisfied. All of the above is neatly expressed in the accounting equation:

$$\text{Assets} = \text{Liabilities} + \text{Proprietorship}$$

Assets are things of value possessed or owned by a business, examples being cash, securities, supplies, accounts owed to the business, land, and buildings.

Liabilities are debts owed by the business to outsiders. Examples are accounts and notes payable, taxes, insurance and wages due and payable, and bonds payable.

Proprietorship, net worth or **equity** are terms expressing the owners' claim to the rest of the assets of a business after all of the liabilities are satisfied.

An example of a balance sheet might be:

John Richards Mining Company

Balance sheet, December 31, 19......

Assets	
Cash	$ 500
Acct's receivable	600
Mining supplies	400
Buildings	250
Mining claims	1,250
	$3,000
Liabilities	
Notes payable (J. Peabody)	$1,000
Proprietorship	
John Richards, Capital	2,000
	$3,000

The balance sheet is dated, showing the time at which the records of the business were summarized. It represents the results of several transactions that had been made previous to that date. The first transaction took place when John Richards invested $2,000 of his own money in the mining business. In order to begin operations, he paid $1,250 for some mining claims, giving Mr. Peabody $250 in cash and his note for

*Deceased

$1,000. Richards has bought $400 worth of mining supplies and has sold $600 worth of ore but has not been paid for it; $250 was spent putting up a building, and $500 in cash remains.

An important difference in the kinds of assets is that some assets must be represented by the cost of land, buildings, and heavy equipment from which the original payment is not returnable for several years. These are the **fixed assets** of a business. In contrast to fixed assets are **current assets,** that is, the cash, securities, inventories, and anything that is easily convertible to cash and is used in the current conduct of the business.

Just as there are current and fixed assets, there are current and fixed liabilities. **Current liabilities** are liabilities that must be paid within a short period of time; at the most, one year. **Fixed liabilities** are the long-term debts. Excess of current assets over current liabilities is **working capital.**

In the example, current assets are the cash ($500), the accounts receivable ($600), and the inventory of mining supplies ($400), a total of $1,500. The current liabilities are represented by only one account, the note payable to Peabody $1,000). Fixed assets are the value of the building ($250) and the mining claims ($1,250). There are no fixed liabilities. Working capital is equal to $1,500 — $1,000 = $500.

The word **Capital** has several meanings, depending upon which way it is used: (1) it may mean the total of the capital stock, capital surplus, and other capital accounts found in the proprietorship section of the balance sheet; (2) it may mean the money gained through the issuance of stocks and bonds; (3) it may mean the total accumulated wealth of the business in tangible and intangible property. This discussion is concerned with financing a business; the second definition will be appropriate unless there is a statement to the contrary.

THE DIFFERENT KINDS OF BUSINESS CAPITAL

One thing that distinguishes type of business capital is the ownership of it. Money invested in a business by the owners, that is the proprietor if it is a single proprietorship, the partner if it is a partnership, or the stockholder if it is a corporation, is known as proprietary or equity capital. On the other hand, capital that is lent to the business by nonowners, or lenders, is known as borrowed capital. Owners may forego, for a time, a return on their investment as long as they see possibility of an adequate return at a future date, but it should not be expected that lenders ever will. It is this difference, that is, that borrowed capital demands a return at specified rate and time, that makes it so important that small businesses, before the profit pattern has been established, should be financed by a greater proportion of equity capital rather than borrowed capital. Indeed, most lenders will see to it themselves that money is not lent to small businesses without the assurance that the owners have enough faith in the business to have invested in it to the extent of their available resources. They will also assure themselves that the proportion of the borrowed capital of the business will not create an unmanageable situation for the business, because if the business fails, so will they lose, in some measure.

Table 11-1 is another balance sheet, illustrating more of the important features just discussed.

TABLE 11-1.—A balance sheet of a typical mining enterprise.

ASSETS*			LIABILITIES**	
Cash	Current assets	Current liabilities	Accrued wages and salaries	Creditors' claim on assets
Negotiable securities	Current assets	Current liabilities	Accounts payable	Creditors' claim on assets
Accounts receivable	Current assets	Current liabilities	Notes payable	Creditors' claim on assets
Notes receivable	Current assets	Current liabilities	Accrued interest, taxes, insurance and other expenses	Creditors' claim on assets
Inventories: Ore, concentrates, etc.; Warehouse supplies	Current assets		Bonds payable	Creditors' claim on assets
Property (claim, land, etc.)			Capital stock or proprietorship	Owners' claim on assets
Buildings and equipment			Contingency reserves	Owners' claim on assets
Prepayments and deferred charges (capital development)			Surplus and undivided profits	Owners' claim on assets

*Assets are listed in order of decreasing ease of convertibility to cash.

**Liabilities are listed in order of decreasing urgency of payment.

IMPORTANCE OF WORKING CAPITAL

Working capital has been defined as the excess of current assets over current liabilities. It may be thought of as the cushion that will sustain a business in operation after all of the creditors have been satisfied, if it should happen that they all would press their claims at once. Working capital is the wherewithal of any business, without which no amount of spirit, desire, ingenuity, or willingness to sacrifice on the part of the owners can sustain the business for long. Numerous failures of small mining operations, and indeed, all types of small business, result principally from the fact that working capital has been depleted.

Working capital is an elusive thing, requiring the best business skills to keep it. It is easy enough to see how working capital may disappear when one considers what happens to the balance sheet when certain typical financial transactions take place. Suppose cash is paid for some mining claims. A current asset (cash) is traded for a fixed asset (the mining claims), and with no change in the condition of the liabilities, the working capital is decreased by the amount of the transaction. Suppose, again, that a note is given for the mining claims, an increase in the current liabilities (notes payable) is accompanied by no increase in current assets, therefore, the same situation prevails, that is, working capital has been decreased. If, on the other hand, capital stock is given for the claims, then the working capital is unaffected because neither current assets nor current liabilities are involved. Borrowing money on a note to pay wages or a pressing debt does not change the working capital picture, because all transactions involve only current liabilities; the only advantage to the business is that the note payable is slightly less current than wages payable.

The working capital situation may be improved by:

1. Making a profit, and inasmuch as the increased cash or other current asset is offset by the owners' claim to the profit, a proprietorship account, the additional current asset increases working capital;

2. Exchanging a fixed asset for cash or a current asset, or to reduce a current liability;

3. Trading any type of a fixed liability or equity claim for a current asset, such as selling bonds or issuing capital stock for cash, or in the case of a one-man ownership or a partnership having the owner or partners invest more money in the business.

WISE MANAGEMENT OF WORKING CAPITAL IS NECESSARY

When a small mine is in the position that it must depend upon capital from outside sources, either from the owner or from some outside supplier of capital; that is, if the mine is still not producing ore from which a profit is being made, then the working capital must be made to provide the most efficient advance toward a profitable operation. The raw material of any mine is ore reserve, and until the position of the mine in regard to its ore reserve is a healthy one, the sinking of working capital into fixed assets such as a mill or unnecessary or elaborate buildings is an unwise business decision.

Mining districts in the west are filled with derelict mills, many of which have never milled a ton of rock; they are monuments to the careless use of working capital. Many an operator of a small mine becomes overenthusiastic about the potential of the mine and builds a mill with the mistaken idea that mills are visible evidence of a mine that is prosperous, and can be used to stimulate the acquisition of capital requirements from uninformed investors. A less common mistake, but nevertheless of sufficient importance to be worth mentioning, is to build a mill without having tested the milling characteristics of the ore. Then, when the mine does produce, the mill may not be able to make an efficient separation of the minerals.

Premature erection of a mill is a serious mistake because of the consequences that are listed:

1. Reduction of the working capital to the point of making it necessary to seek more outside capital;

2. Placing the mine operator at the mercy of his creditors, if any portion of the mill has been financed;

3. Tying up capital in a fixed asset, the use of which can return the investment only by milling ore. Salvage value of mills is only a very small percentage of the purchase price. Also, the value of a mill as collateral for borrowed capital is practically nil.

Serious-minded investors of capital in mines are not looking for mills, they are looking for ore reserves. Mills erected on mining property where there is very little or no ore showing will cause any person familiar with mine finance to conclude that the management of the property is not realistic.

Tying up capital in a mill and in the expenses of erection that are essential after the mill is purchased is justified only when it can be shown that ore reserves are sufficient to pay off the cost of the mill, and only after there has been an adequate testing program on large samples of the ore, from which it is possible to determine a workable flowsheet.

The manager of a small mine should limit his initial investment in fixed assets to the minimum necessary to maintain the operation on a modest scale until profit from the operation is assured. By limiting the investment in fixed assets as much as possible, he maintains the most flexible financial position.

MINE FINANCING REQUIRES 'RISK' CAPITAL

Mining is different from other types of businesses in several respects. The ore upon which the mine depends for providing the profit to the business is never completely measured in amount or value; therefore, a probability factor is associated with any estimate of the ore reserves. The probability that the estimate of the amount and value of an ore body will be the true amount and value will increase as the number of samples increases. As there is a limit to the amount of money that can be spent for sampling, mine operators have learned to accept the fact that there is only some degree of probability that a mineral deposit will become a profitable venture.

A second very important fact about mining is that whatever the ore body happens to be, in volume, value, or composition, even though it cannot be measured completely, it is not changed through the process of nature. The consequence of mining is that value is continually being taken away without any other value replacing it. This leads to the concept that the raw material of the mine, the ore, is a wasting asset.

Finally, the day when a mine will make a profit "from the grass roots" has long been gone except where there is an extremely rare combination of favorable factors. One factor that can enhance this probability is the suddenly developed need for a mineral or metal that hitherto had not been of particular value (recall the sudden impetus given to the mining of uranium ore by the advent of the atomic age). The most usual chain of events in the history of a mining venture is a long period of time for examination, exploration, and development, wherein much money is spent before the returns from the ore exceed the cost of operation.

The need is thus established for 'risk' or 'venture' capital, so named because of the fact that it must be invested in the business as working capital and as fixed assets before there is a full knowledge of the profit-making potential of the business.

ESTIMATION OF CAPITAL REQUIREMENTS

Before the final commitment of more than casual funds to the furtherance of a mining venture, it must be established that there does exist now, or there is a prospect for, a sufficient amount of potentially commercial grade of a valuable mineral, and that the deposit is favorably located with respect to power, water, labor supply, and transportation. There must also be an available market, or a strong potential for developing one. Only after these conditions are assured, should the potential mine manager commit himself to serious financial obligations in the continuation of the venture. A mining engineer's evaluation report may be obtained to answer the questions about the feasibility of the undertaking.

Also, a mining venture should not be embraced without a fairly good idea of the amount of money that is going to be needed to bring the property to a self-sustaining operation. Without this knowledge and a clear understanding as to the source of the capital that will be needed, the venture is doomed to failure.

ESTIMATION OF AMOUNT OF FINANCIAL NEED

The amount of capital necessary to bring any prospect to the producing stage will vary with changing price levels and labor costs, technological progress, uncertainties of price or demand for the product, as well as the peculiar conditions associated with each particular ore body.

Schedules 1 through 4 are designed to assist in the systematic estimation of the capital requirements of a small mine. No schedule can be made to be entirely general; deficiencies may become apparent for every problem in which it will be used; but it is hoped that individual deficiencies are minor in relation to the good that can be served by a tabulation that can be readily inspected.

The difficulty of arriving at satisfactory figures to put in the appropriate columns is realized. All of the prospective manager's ingenuity must be brought to bear in order to get reasonable cost figures. He must talk with other operators in the vicinity and ask numerous questions; he must read the technical and trade magazines for scraps of information giving him a clue to the various costs (not failing to investigate the advertisements listing machinery for sale); he must talk with local machinery salesmen, contractors, businessmen, and managers about machinery costs, labor costs, and opportunities for cost reduction; finally, he must develop the habit of jotting down the various scraps of information he collects in notebooks so that he may refer to the notes at appropriate times as the cost estimate is being drawn up.

It must be realized that the completed schedules will be only estimates derived by making many smaller estimates, and that all estimates carry some amount of risk. The degree of certainty is directly proportional to the effort that went into determining the accuracy of each estimate. Here again, realizing that perfection is never possible without the expenditure of a prohibitive amount of money and effort, one must be satisfied with some risk, and be willing to accept the final results with appropriate reservations.

SCHEDULE 1.—Work sheet to estimate initial capital requirements for buildings, equipment, and initial inventories.

Item	No. needed	Cost[2]		Installment price or rental			No.[3] payments	Instal-lation cost[4]	Total
		New	Used	Down payment	Periodic payment	Rental payment			
Buildings: Machine shop Hoist house Shop Dry Office									
Hoisting equip.: Headframes Ore bins Hoist Wire rope Cages, skips									
Power installation: Poles, transformer[1] Diesel, gas eng.									
Air compressor:									
Drilling equip.: Comp. air lines Water lines Drill and steel									
Drainage: Pumps w/motors Lines									
Ventilation: Fans w/motors Tubing									
Haulage: Scrapers, slushers Mucking machines Locomotives Track, switches Cars Trucks									
Miscellaneous: Bulldozer Prospecting drill Survey equip.									
Initial Inventories: Tools Timber Supplies Explosives									
TOTAL									

[1]See local power company.
[2]If cash is paid, enter amount in last column.
[3]Until mine is producing.
[4]Include freight, commission, and erection cost.

SCHEDULE 2

Work Sheet to Estimate Nonrecurring Capital Requirements

Property Acquisition and Habilitation		
Purchase of claims, lease, or other rights		
Purchase of real estate (other than above)		
Legal fees		
Access road, ... mi., at $........ /mi.		
Cost of water rights, ponds or dam, flumes		
Total of Schedule 1		
Deposits in escrow		
For public utilities		
Other		
Cash		
For working capital		
For contingencies		
Total		

SCHEDULE 3

Work Sheet to Estimate Recurring Capital Requirements Per month

Salaries		
Officers, proprietors, or partners		
Others		
Depreciation		
Insurance		
Workers' compensation		
Fire, theft, etc.		
F.I.C.A.		
Other		
Taxes		
Licenses		
Other		
Rent, heat, light		
Telephone, telegraph, postage		
Miscellaneous		
Total		

SCHEDULE 4

Work Sheet to Estimate Capital Requirements of a Small Mine

Total of nonrecurring capital requirements (from Schedule 2)		
Exploration		
Diamond drilling, ...ft., at $........ /ft.		
Other exploratory drilling, ...ft., at $...... /ft.		
Trenching, (units) x (cost/unit)		
Test pits, (units) x (cost/unit)		
Shaft or winze		
Rehabilitation, replacement of timbers, repairs		
Sinking, ... ft., at $ .... /ft.		
Stations		
Tunneling, crosscutting		
Rehabilitation, replacement of timbers, repairs		
Driving, ... ft., at $....... /ft.		
Raising, ...ft., at $........ /ft.		
Geological service, ... mo., at $........ /mo.		
Mining		
Stope preparation		
Mining first ...... tons, at $ .... /ton		
Overhead		
Assessment work on .... claim for .... years		
Monthly expenses (from Schedule 3), for .... mo.		
Total capital needed to bring mine into production		

ESTIMATION OF TIME SEQUENCE OF FINANCIAL NEED

It is seldom necessary to actually possess all of the financial requirements before any work is started, because of the time involved between the start of work and the actual mining operations. It is necessary, however, to have plans developed whereby the time sequence of each phase of the operation is scheduled, and the appropriate provision for the various amounts of money also scheduled. A general analysis of time and money involved in a mining venture has been summarized by Lipsey (1952, p. 784) from which Table 11-2 is reproduced.

As a short explanation of the table, it should be noted that under the heading of Units of cost, the comparison between the cost of each stage of development is comparative only, hence the absence of actual dollar figures in the fourth, fifth, and sixth stages.

As in the case of the advisability of a mining venture being investigated by a qualified mining engineer, a realistic time sequence of operations can be made only by one experienced in such matters. If the prospective mine owner does not have the required knowledge and experience, then it is imperative that he employ technical help in this phase.

OBTAINING THE CAPITAL

In any business, there must be a source from which capital is obtained. All businesses are started by an investment of capital by an individual or group of individuals or by the sale of stock in a corporation, and if the amount of the initial investment is sufficient to carry the business through its formation and until the time it can make a profit, the business should have no need for additional outside capital. Often, however, when unforeseen events take place, if there is a miscalculation in the capital requirements before the business becomes profitable, or if it is advisable to expand the business, additional capital may be required at times after the initial financing. This section will discuss the several different sources from which the initial capital requirement of a business may be obtained, as well as pay some attention to the sources of capital as it may be needed from time to time in order to sustain the business.

TABLE 11-2.—Stages of mining development from discovery to production.

Stage of development no.	Financing	Units of cost	Time interval
1. Discovery	Prospector Grubstake Govt. assistance Mining company	a few hundred dollars to 1 unit	1 to 20 years
2. Preliminary examinations	Individual Partnership Syndicate Mining company	a few thousand dollars to 1 unit	a few weeks to several months
3. Preliminary development. Includes surface trenching, diamond drilling, geological mapping, geophysical or geochemical prospecting, and in some cases underground work	Partnership Syndicate Sale of stock in company formed to develop the prospect Funds provided by mining company	Several thousand dollars to 2 units	6 months to 3 years
4. Underground development to block out positive ore reserves	Sale of company capital stock Funds provided by mining company	30 units	2 to 5 years
5. Installation of a mining and treatment plant. Includes the development of the mine for mining, the mining plant, the treatment, power, and water supply, transportation, facilities, and townsite	Further sale of company capital stock Funds supplied by mining company Bank loans obtained by an established company Sale of bonds	83 units	2 to 3 years
6. *Tune-up period merging into production stage	Working capital, which must be provided from the above sources or generally by a bank loan until returns from the operations are made available	7 units	1 to 6 years

*Cost of property must be provided for and may range from 1 to 20 units (Reproduced by permission).

CONTRIBUTION OF THE INDIVIDUAL

The simplest form of business is the individual ownership, which is the case when one person invests his own money in a business enterprise and realizes all of the profits therefrom.

It must be kept clearly in mind that the proprietor must keep the affairs of the business completely separate from his own personal and household accounts. On the other hand, the business is dependent upon the individual to provide the entire initial needs of the business, and in fulfilling that requirement, the individual must sometimes find his own sources of capital.

Prospective investors in or lenders to a business do not become impressed unless they see that the owners of the business have provided a major part of the needs of the company. They normally expect that owners of enterprises of unproven character provide 50 to 80 percent of the capital requirements.

Most small businesses are started by unencumbered savings of the owners, but it may be necessary for individuals to obligate themselves so that they can invest in the business in order to bolster its financial position. Several sources of emergency funds are available.

Life insurance policies.—Life insurance policies that have been held for some minimum length of time provide collateral for a loan from the insurance company. The conditions of the loan and amount of the loan value of the policy are always stated on the policy. Interest is generally at a reasonable rate, and there is generally no time limit for repayment.

Character loans.—Character loans are often extended to individuals of unblemished credit rating by local banks or some individuals. Such types of loans are generally made on unsecured notes for a short time, and most call for interest at the going rate.

Mortgages on real estate.—Because of the durability, fixity of location, and accessibility of real estate, it is often used to provide security for loans not exceeding a certain percentage of its appraised value. In Montana, a mortgage is not regarded as a transfer of title, but the title to the property may pass to the mortgage holder in the event of a foreclosure. There may be more than one mortgage on a piece of property, but the cost of second and third mortgages increases as the total appraised value of the property is approached by the total value of the mortgages. Savings and loan associations, mutual savings banks, and commercial banks are possible sources of money. Loans secured by mortgaging real estate are generally long-term loans (they may extend for several years), and usually are repaid according to a predetermined plan of periodic payments, each of which includes payment of interest and repayment of a portion of the principal.

Small loan companies.—Small loan companies specialize in loans to individuals of not more than $1,000. Once the loan is made, the loan company embarks on a program of aggressive collection techniques and imposes rigid repayment schedules. Because of fairly high interest rates, reflecting the riskiness of such a business, and the imposition of penalties, handling charges, and other items of hidden interest, capital acquisition from this source is of dubious value, only to be considered in an extreme emergency.

PRELIMINARIES TO THE SEARCH FOR OUTSIDE CAPITAL

Capital must be solicited from others when the individual sources are entirely committed. Two types of capital may be solicited; equity capital and borrowed capital. When equity capital is sought, the payment that must be made is a portion of the management of the business; when borrowed capital is obtained, it must be paid for by obligating the business to pay interest at specified time intervals and eventually to pay back the principal. Whichever type of capital seems to be the more attractive, the campaign to raise it must be well thought out and planned.

When the capital needs of the organization have been determined and the decision is made concerning the type of capital to seek, a written presentation of the facts that would be of interest to the prospective supplier of money must be prepared. This presentation is known as a prospectus, and must be written differently depending upon which type of capital is being sought. A word of caution might be inserted at this point mentioning the necessity for factual information in any prospectus, especially if it is to be distributed through the mails. Although glowing terms of how much ore **might** be discovered and how rich it **might** be after it is found, and glittering generalities about the grandiose plans and promises of fabulous profits might impress widows and the uninformed, such practice, even if it can be done by circumventing federal mail fraud laws and regulations, is as out-of-style as the horse and buggy. The more enlightened investors require that the prospectus contain nothing but facts that can be substantiated.

The prospectus prepared for potential investors—This type of prospectus will serve to introduce your business proposition to prospective partners or shareholders. As a starting point, it should contain the following information:

1. Give the name, firm name, mailing address, business location, and telephone number;
2. State the nature and purpose of the business;
3. Tell the form of business that you propose;
4. State the type of partnership or degree of participation that you desire in an investor;
5. Tell what will be the potential business associate's share of the business;
6. State the qualities desired in a partner or associate, also how these qualities will be compensated, in salary or in shares;
7. Review the history of similar ventures in the locality, the more closely associated with the business at hand, the better;
8. Explain the workings of your business, in as much detail as possible. Any factual records of samples, ore widths, examination reports, or other reliable information may be presented;
9. If your business has been in operation, include financial statements with assets as well as liabilities listed, also include information on any unusual financial dealings that are to be expected in the near future;
10. State, and justify, your opinion as to the potential of the business;
11. Give details of your own personal business history;
12. Give the reason for seeking money. State whether the money will accelerate the progress of the business;
13. Furnish references; the best kind are those who are recognized as financial authorities — banks, credit bureaus, business firms — rather than personal friends;
14. Furnish any other items such as newspaper reports, other publicity, and pictures, that will help the prospective investor know your business.

The prospectus prepared for lenders. — A slightly different approach must be taken when borrowed money is sought. The information is much the same as is contained in any application for a large loan.

1. Give general data as before; name, name of the business, mailing address and business address, telephone number;
2. State the form of the business, whether private ownership, partnership, or corporation, with names of partners and other responsible

parties. If the business is a corporation, state the details of the corporation such as capitalization, amount of capital stock outstanding, who owns the stock and in what proportion, how much stock is paid for and how much is held in reserve;

3. State the nature of the business and the history of it;

4. Give age, marital status, and information as to personal bank accounts, insurance policies, and other sources of income of principal parties. Name the civic and business associations of the principals;

5. Give information on business connections; banks, suppliers, those to whom your product is sold, where money is owed, and from whom money is due;

6. State details of the loan; the amount, the interest, the security for the loan, the plans for repayment, who may guarantee the loan, and the time required for payment;

7. Refer to the purpose of the loan—if it will be self-liquidating, and if it is for a legitimate purpose; if it is for replacement of equipment or purchase of new and better equipment, or if it is for payment of other pressing debts of a more urgent nature;

8. Furnish as complete financial statements as possible, listing business assets and liabilities brought up to a recent date. Include the most recent profit and loss statement, and include in the latter some reference to how much money was withdrawn from the business by the owner or partners, or what dividends have been declared;

9. Other business information often found necessary are a statement that social security and other taxes have been paid, the interest of other parties in the business, such as holders of large blocks of outstanding stock or large bondholders, and explain the extent of the interest. Statement of future prospects, plans, or probable outlook is not out of place. Any factual information placing the proposition in a favorable light should be included.

By far the most important selling point for the individual when he is seeking outside capital, whether it is equity capital or borrowed capital, is an unblemished credit rating with the local credit associations and bureaus, banks, business firms, and individuals. Much can be said about the importance of providing factual data in prospectuses, engineers' reports, and other statements concerning the business, but it can be all to no avail unless the individual is able to withstand scrutiny by lenders who make it a habit to make inquiries of all sources of information available to them.

Wise businessmen go to great lengths to cultivate and maintain the best credit rating possible, and will spend time and effort developing their reputation. Indeed, it is common that business deals involving considerable sums of money will be consummated solely on the reputation of the participants and a hand shake.

A point to consider when planning a campaign to raise capital for a mining venture is the timing. When the prices are high for the product of the mine in which there is an interest, venture capital is much more readily available than when the prices are low. Legislation favorable to the industry, government assistance programs that tend to stabilize the market for the product, or similar changes for the good of the mining industry provide impetus for those with venture capital available to seek places wherein they may invest their money. Conversely, when the price level of metals is at its lowest point in many years, even though the metals may not be the product of the particular mine in question, the generally depressed atmosphere in mining will discourage anyone from investing in it.

When borrowed money is sought, the timing of the borrowing must be planned well in advance. One will find that it is easier to borrow money when he can prove that he does not need the money than when he is so pressed by creditors that his back is against the wall. Therefore, it should be the rule of any anticipated capital-raising venture that the needs for the capital should be anticipated well in advance so that each phase of the negotiation may be carried out at the most opportune time. It is extremely important that financial negotiation should take place in a relaxed atmosphere, and that can only be the case when no pressing financial requirements are plaguing the borrower.

PROMOTION

When a person advertises the fact that he is seeking money to be invested in some business, he is promoting. Promotion takes many forms, from direct advertisements in papers and periodicals that are read by the class of people that the promoter wants to interest, to the most subtle means involving personal persuasion and the use of personal contacts.

Promoting by advertising. — Trade publications, financial publications, newspapers, and magazines are only a few of the types of media that can carry the message of the promoter. An advertisement in Engineering and Mining Journal, a publication read by many who are interested in mining, is an example (certain facts are disguised):

> MINING CAPITAL WANTED. $10,000 buys 49% interest in five Montana deposits . . . John Jones, 100 Elm St., Chicago, Ill.

Advertisements for the purpose of promotion are generally placed either in the classified section of the publication under "Business Opportunities" or as a display advertisement in the financial or business section of the publication. Considerable attention must be paid to the make-up of the advertisement, because brevity, consistent with providing as much information as necessary to stimulate interest, is the most important consideration.

Promotion through contacts.—Contacts are individuals or groups with whom a person is acquainted; his friends, business associates, fraternal club members, fellow church members, relatives; in fact, all persons to whom the promoter can tell his story and expect that the contact will eventually lead to a financial transaction between the promoter and an investor. Successful promoters are the ones who enthusiastically discuss their proposition at any opportunity where they think the information they impart will reach the right individual. They are naturally social-minded so as to have many influential friends, and are well versed in the subtleties of personal persuasion and the techniques of salesmanship.

A list of the most important contacts that should be approached first would include one's banker, lawyers, insurance agent (because they know who has received large amounts of money through insurance benefit and are often consulted by persons who do not know what to do with it), accountants, business club members, Chambers of Commerce, and editors of local newspapers. There may be civic groups in the area, or development corporations, who are particularly interested in promoting industry in the state or locality; they would certainly have some knowledge of the business situation and consider it their business to offer helpful advice.

Once a lead has been developed, it should be pursued to its conclusion with enthusiasm and single-minded purpose. **But,** be prepared to accept the fact that others may not feel as enthusiastic about the proposition as the promoter; consequently, a refusal or even a great number of refusals, should never dampen the promotor's spirit.

SOURCES OF EQUITY CAPITAL

PARTNERS

When the requirements for the initial capital of a small mine can be met by pooling the resources of two or more individuals, the individuals may enter into a partnership. The partners may all be active in the business, in which case the arrangement is known as a general partnership. Contributions to the business, besides capital, may be some skill such as managerial experience, technical experience, or financial managerial skill. The main disadvantage of a general partnership is that each partner is personally liable for all of the debts of the partnership. When a general partnership is formed, a written agreement covering the following points is recommended.

1. Firm name, including all partners;
2. The business of the firm;
3. The nature of the contribution by each partner;
4. The length of time the partnership is to exist;
5. The amount of time that each partner should contribute to the business;
6. The limit of authority and area in which authority is to be used by each partner;
7. Manner of division of profits and losses;
8. Conditions of withdrawals from the business, and salary of each partner;
9. Procedure for admitting new partners;
10. System of dissolving the business by voluntary action;
11. Protection of the firm upon death of a partner, such as taking out insurance on partners, appraisal of assets and liabilities.

The principal advantage of a general partnership is that it has the best credit rating of any form of organization, especially for short-term loans, although long-term loans may be harder to obtain because of the fact that death or incapacity of one of the partners, or voluntary dissolution of the partnership, causes a liquidation of the business. Besides the financial responsibility of each partner for the firm's debts, there is the liability of each partner for another partner's actions.

A limited, or silent, partnership is the condition wherein one or more individuals furnish capital to a business for a share of the profits of the business, but do not participate in the management of it. The advantage of bringing a silent partner into the business is that the business management remains as before; no control of managerial policies is lost. A limited partner is not liable for the debts of the partnership beyond the amount of his financial participation, nor is the partnership responsible to the silent partner when the business fails to be profitable. A silent partner would be more inclined than a lender to invest additional capital in a business that needs financial assistance when experiencing difficulties, because it is reasonable to expect that the silent partner would be interested in saving his investment.

Montana law requires that when a limited, or special, partnership is formed, a certificate must be signed and sworn to, stating the following:

1. The name of the partnership;
2. The character of the business;
3. The location of the principal place of the business;
4. The name and place of residence of each partner, general and limited partners being respectively designated;
5. The term for which the partnership is to exist.
6. The amount of cash and a description of

and the agreed value of the other property contributed by each limited (silent) partner;

7. The additional contributions, if any, agreed to be made by each limited partner and the times at which or events on the happening of which they shall be made;

8. The time, if agreed upon, when the contribution of each limited partner is to be returned;

9. The share of the profits or other compensation by way of income that each limited partner shall receive by reason of his contribution;

10. The right, if given, of a limited partner to substitute an assignee as contributor in his place, and the terms and conditions of the substitution;

11. The right, if given, of the partners to admit additional limited partners;

12. The right, if given, of one or more of the limited partners to priority over other limited partners, as to contributions, or as to compensation by way of income, and the nature of such priority;

13. The right, if given, of the remaining general partner or partners to continue the business on the death, retirement, or insanity of a general partner;

14. The right, if given, of a limited partner to demand and receive property other than cash in return for his contribution.

The certificate containing the details of the limited partnership, as agreed, should be filed with the county clerk and recorder.

Laws in other states may differ.

VENTURE CAPITALISTS

Venture capitalists are those who use a certain percentage of their personal resources as risk capital, hoping to reap very large profits on investments wherein the risk is compensated by the profit potential. Venture capitalists may be individuals who specialize in a certain type of activity such as mining or 'wild-catting' for oil, or they may be associations of persons in the form of partnerships, clubs, or corporations, and take on such names as partnership clubs, search and exploration syndicates, development syndicates, or finance syndicates.

Venture capitalists do not advertise, so the promotor must search them out through personal contacts. Needless to say, venture capitalists would not be in business very long if they were not shrewd in their financial dealings, or if they rushed into every business venture proposed to them. The burden of making a convincing presentation is on the promoter; consequently, the enlisting of venture capital entails a well-planned campaign, convincing details, and the willingness to foresake a large portion of the profits if and when the property comes into production.

On the other hand, venture capitalists are very nearly the only source of equity capital available to small mines with very little developed ore showing. Regularly organized investment companies generally require a history of profitable operation, which is not possible with prospects, of course. Inasmuch as venture capitalists need account to no stockholders except themselves, they perform a good service in financing small prospects.

Venture capitalists often require a higher return than the maximum lawful rate of interest. Payment for the equity capital derived from this source is in the form of a portion of the profits of the mine when it becomes a producer. Most generally there must be a partnership agreement drawn up, covering at least all of the points in the limited partnership agreement mentioned in the preceding section.

The grubstake was the original form of participation between venture capitalists and the promoter, and it took the form of an agreement whereby the needs of the prospector were satisfied in return for a large share, usually half, of his findings.

SMALL BUSINESS INVESTMENT COMPANIES

Small business investment companies are formed under the authority of the Small Business Investment Act, Public Law 85-699, 85th Cong., approved August 21, 1958. This Act authorized the establishment of privately and publicly owned and operated small business investment companies and delegated to the Small Business Administration the responsibility for licensing, regulating, and helping to finance these new organizations. SBIC's are offered liberal tax advantages and other inducements by the federal government to stimulate and encourage small-business concerns. Nothing in the charters of some of the presently operating investment companies precludes the mining industry from their field of endeavor as long as the prospective borrowers of their funds comply with the requirements they set up before money can be lent.

Small business investment companies are privately owned and are intended to be operated on a profit-making basis. They are set up to provide long-term venture capital by investing in any small-business concern believed to possess growth potential, and to provide management counseling services to such concerns. It will normally be expected that the directors of SBIC's will require proof of growth potential, and to the extent that their investment is expected to be returned in about five years, they would certainly be expected to require all the information about the business that is normally supplied to any other investor.

Additional information relative to Small Business Investment Companies may be obtained from:

Investment Division
Small Business Administration
1441 L Street N.W.
Washington, D.C. 20416

Local bankers should have information about SBIC's in any particular locality.

EXISTING MINING COMPANIES

All mining companies, in order to remain in business, must replenish their ore supply to take the place of depleting reserves. The exploration department of the company may be able to take care of the needs in the vicinity of the operating mine, but occasionally the company must extend the range of its search. Many of the larger companies now employ scouts to range over the country seeking leads that may develop into an operating mine for them.

Some companies specialize in a particular product. Iron ore mining companies of which the M. A. Hanna Co. is an example, will investigate iron deposits brought to their attention. Other companies seek to diversify; for example, Bear Creek Mining Company is a subsidiary of Kennecott Copper Corporation and has been established for the purpose of investigating any likely mineral deposit, not necessarily copper, that has the potential of developing into a mine.

It is not the mining company's business to provide equity capital to small mines; therefore, it is natural that the company would require that it take over the management and operation of a mine in which it invests. This seems somewhat removed from the subject of financing of a small mine, but it is an alternative by which the owner of a mineral deposit, if he finds all other possibilities for acquiring outside equity capital for his mine closed to him, may derive income from his ore body. It is also possible that the owner of a mineral deposit is not inclined to expend the effort and investment necessary to raise the required amount of money, and this method of operation may solve his problem. Instead of a promoter he now becomes a vendor, and he may enter any one of four types of agreements.

Purchase. — The mining company may purchase the patented claims and the vendor's other property rights if a satisfactory agreement on price can be reached. There are many obstacles in the path of such an agreement, however, so other types of financial arrangements are more popular.

Option to purchase. — In this type of agreement, the price asked by the vendor may seem reasonable to the officials of the mining company, but a final agreement cannot be reached until the company satisfies itself that the price is right. The company then takes an option on the property and works toward the satisfaction of the decision. At the end of a specified time, the mining company must continue with the purchase, or it must give up its right to any further activity. The agreement will contain provisions for the method of payment to the owners for any ore taken from the mine by the company during the option period, that is, from the giving of the option until the expiration date.

Lease on royalty basis.—If there is no possibility of arriving at a satisfactory price to be paid for a mineral deposit, it may be leased for a royalty. Under this arrangement, the agreement must provide for purchase or payment of damages for the use of the surface that is needed in the conduct of the mining operations, including the land upon which the waste is disposed. Royalty may be paid at the rate of so much per ton for all ore shipped; in a district where this type of mining is common this may be a set price, but elsewhere it may be a fixed percentage of the smelter returns. In more complicated situations, sliding scales are established dependent upon grade of ore, value of ore, presence of certain valuable or undesirable constituents, or other conditions.

For example, royalty payment might be a flat rate of 20¢/long ton for iron ore containing 48 percent or more of iron; or, sliding-scale royalty payments have been used on the Colorado Plateau in making payments for uranium ore, ranging from 10 percent of the gross value of ore containing 0.2 percent of U_3O_8 or less, to 30 percent of the gross value of the ore containing 0.3 percent to 0.4 percent U_3O_8.

Royalty payment agreements are made for definite time intervals, but provisions are always included that allow extensions of the agreement. In the vendor's favor are the general provisions for minimum royalties, the method of working, in light of maintaining the mine and using safe practices, continuity and diligence of working, inspection of the workings by the owner or his agents, and ownership of property improvements and the waste dumps. Also in the owner's or vendor's favor is that he starts receiving income as soon as production is started and does not have to wait until the initial investment of the company is paid off.

Participation. — Participation agreements allow the owner or vendor to participate in the profit of the small mine when it is operated by a mining company. These agreements allow the mining operator to utilize the first profits of the enterprise to repay the initial investment in development work and other expenses that must be advanced before the mine starts making a profit, after which the operator and owner participate in the profits in predetermined proportions. When the operation is a small one, participation in profits ranges from 50-50 to 75 percent to the operator and 25 percent to the owner. If the mining operator must make a large investment in order to establish himself, the proportion may be as low as 15 percent to the owner. Profit participation is often accomplished by the owner retaining a certain percentage of the equity in the business; if the mining company incorporates the venture, the owner is given a number of the shares in the newly formed company. All rights of management and operation are in the hands of the operating company.

An advantage in seeking capital from established mining concerns, and one that will tend to offset the disadvantages in losing managerial control of the property, is the fact that existing mining companies are experienced in operations and generally have the staff all organized for profitable operation. Also they have equipment for the job and possess sufficient capital of their own to weather the long period of development preceding production. They also have their own marketing facilities.

PUBLIC FINANCING

Public financing, in the meaning that is intended here, entails the procedure of incorporating and selling stock in the corporation. It is not the purpose of this writing to discuss fully the technique of the procedure, because this step is beyond the 'do-it-yourself' category. The legal requirements are so involved that it is imperative that a lawyer experienced in these matters should be retained if it is decided that incorporation is desirable.

The corporate form for doing business has certain advantages over individual ownership, the most important of which is the manner in which it is possible to finance the business by selling stock. Regulations imposed by government to control fraudulent stock promotion schemes contribute to the complexity of corporate financing.

If an enterprise needs to raise $300,000 or more by the sale of stock, and if the stock is to be sold to the general public and also to investors living in other states, the corporation must be registered with a federal agency, the Securities and Exchange Commission (SEC), whose purpose is to provide investors with information about the securities that are offered for sale and to condemn fraudulent dealings and misrepresentation.

Details of regulations, services, and other information concerning the activities of SEC may be obtained from the main office of SEC:

Securities and Exchange Commission
500 North Capitol Street N.W.,
Washington, D.C. 20549

Small mines need not come under the provision for registration with SEC if they are to be capitalized for less than $300,000, or if the stock is to be sold privately within a small group of friends or associates within the state. The SEC requires only that it be notified on one of its standard forms.

The advantages of incorporating and selling stock are these:

1. The corporation has the same rights as a person; it can own property, collect money, sue and be sued, and the stockholders have only limited liability for the debts of the corporation, up to the amount of stock that they hold in the corporation.
2. Small and large investors may be accommodated, because the stock is subdivided into shares.
3. The corporation is capable of maintaining itself for a long life, regardless of the fortunes or misfortunes of the incorporators, thus making it easier to obtain long-term loans than when the business is a partnership.
4. Shares of stock may be easily traded by the investors.
5. Control of the corporation may be maintained without necessarily holding the majority of the shares of stock.
6. A corporation may grow by retaining some of the profits in the business, if the stockholders approve.

Partly offsetting the foregoing advantages are a few disadvantages:

1. Legal and organizational expenses may be large.
2. Corporate income taxes may be burdensome to small mines.
3. The corporate charter limits the business of the corporation.
4. A corporation requires more extensive and expensive record keeping to satisfy all persons concerned with the corporation—the stockholders, officers, and government agencies.

Once again, if it is decided that the corporate form for conducting the business will offer advantages overshadowing the disadvantages, there are two things that must be done first:

1. Embark on a serious program of self-education that must necessarily go far beyond the generalities of this handbook.
2. Get legal advice.

SOURCES OF BORROWED CAPITAL

Borrowed capital carries with it the obligation to repay the amount borrowed plus interest. It can be a boon or a burden to any struggling small business; if, by use of borrowed money, the business can profit by more than the interest, then the borrowed money is a benefit to the business. If, on the other hand, the borrowed money cannot be put to work to advantage and earn its own interest, then the obligation to pay the interest becomes a millstone around the neck of the borrower.

GOVERNMENT ASSISTANCE

The development of government's attitude toward financial assistance to small business.—The United States has become great through the successful application of the principles of the capitalistic system, which has as its driving force the aspirations, initiative, ambition, and effort of the individual. In the colonial and post-colonial times, the freedom of the individual to pursue his interests in his own way led to the establishment of small businesses, trades, and enterprises. When several enterprises of the same character developed in a locality, competition resulted. It was seen that peaceful competition was good for the development of our industrial society because it required that in order to be successful and survive in the face of vigorous competition, the businessman was forced to improve continually the quality of his product or of his service.

With the growth of the corporate form of business, which allowed businessmen to apply great amounts of capital toward the prosecution of a business, and through the growth of the individual corporations by retention of profits in the business, some of the more successful of the competing business units became large and powerful. They became so powerful that in their ambitious and zealous attempts to follow the path of competition to its very end, they became strong enough to eliminate all competition. It was found necessary for Congress to pass the Sherman Anti-Trust Act of 1890 in order to impose some governmental regulations upon big business and to eliminate monopoly.

Passage of the Sherman Anti-Trust Act was the beginning of the evolution of a philosophy of the government that has finally developed. It now appears that the government's attitude toward business may be somewhat summarized in the following generalizations:

1. Competition is good because it assures the best product for the lowest price; therefore, it must not be possible for competition to be eliminated.

2. New business must start from small business; therefore, it must be possible for small business to form in a protective environment, in much the same manner as infants of any of the animal species must be protected from the predators.

3. Too much assistance or protection is bad because it allows weakness to develop in the protected; therefore, assistance should be limited to that which will develop self-sufficiency and shall not be something that must be continued indefinitely.

If the above were to be summarized, it could be said that the attitude of the government toward assistance to small business is to provide the means by which the small businessman can help himself, and to maintain an environment in which the struggling businesses may grow and compete on a fair and reasonable basis — that each businessman has equal opportunity, regardless of the size of his business.

So much for the philosophical aspects of aid to small business in general; there are much more practical aspects in the attitude of the government to the mining industry in particular.

Because of the fact that mineral deposits are so distributed about the world's surface that no nation has equal supplies of all of the minerals, and also because of the fact that in times of world conflict the emergencies of supplying the needs for the war effort require a continuing supply of the mineral raw materials, national interest forces the government to assure itself the best supply of raw materials. In order to do this, the government offers various types of incentives for any and all who might be able to supply the needs.

On the one hand, a business that cannot produce efficiently in competition with others should not be specially favored, but on the other hand, if the national emergency is such that survival is at stake, production must come from all sources, and then it is not a question of favoring anyone, but of stimulating production of all businesses and providing the necessary inducement to develop the raw material supplies that we need regardless of the peace-time philosophy. The government's interest is in the preservation of our way of life; its policy of assistance to small mines may be justified and influenced by the need to:

1. Stockpile the anticipated requirement of the strategic and critical minerals that are not normally produced in the United States in sufficient quantities for our needs, and for which we must make extra provision if foreign supplies are cut off by naval blockade or because the supplier is in the enemy camp;

2. Locate, catalog, and classify the mineral deposits that we do have;

3. Maintain stability in the mining industry so that when an emergency is forced upon us there will be an industrial organization and developed ore reserves immediately available.

A third line of activity by the government comes from the growing tendency to direct, control, and influence the economy of the country as a whole. Inducements to encourage formation of small businesses to stimulate employment in depressed areas, and to increase the circulation of money, are temporary measures and have been used in the past and will be used in the future.

Short historical review of government agencies making loans to small mines.—From time to time, there have existed, in the federal government, agencies set up to carry out one or more of the objectives outlined above.

The Reconstruction Finance Corporation (RFC) was a financing agency formed to stimulate economic recovery from the great depression of the 1930's. The RFC lent money to a few mining operations but they required substantial subordinate financial participation by the borrower, and the property had to have easily proved substance and feasibility. The RFC is no longer operating.

The Defense Minerals Exploration Administration (DMEA) was set up in 1950 under authority of the Defense Production Act for the purpose of encouraging the exploration of 34 strategic and critical minerals that were essential to the national security at that time. Under a DMEA agreement, the government would finance part of the costs of exploration, paying 50 to 90 percent of the total cost of the drifting, shaft sinking, rehabilitation procedure, crosscutting, or raising that had as its objective finding and exploring deposits of the critical minerals. The DMEA was replaced by the Office of Minerals Exploration in 1958.

The Defense Minerals Procurement Administration (DMPA) had a slightly different function to perform in that it was organized primarily for the purpose of stimulating new production of the strategic and critical minerals. Methods employed were outright purchase, minimum price guarantees, loans to producers, assistance in the procurement of equipment, and direct subsidies. The DMPA was not a financing institution as such, but had the purpose of seeing to it that the government obtained its critical materials by any means.

When the government's stockpiling program was completed, and the national emergency was no longer upon us, DMPA was discontinued.

Office of Minerals Exploration. — The OME was authorized by Congress in 1958. It succeeded the Defense Minerals Exploration Administration and it administered the contracts still in force that were made with that office.

OME conducted a program of financial assistance to small mines and mine operators by furnishing part of the costs of exploration for specified mineral commodities such as:

Antimony	Mercury
Asbestos (strategic)	Mica (strategic)
Bauxite	Molydenum
Beryllium	Monazite
Bismuth	Nickel
Cadmium	Platinum group metals
Chromite	Quartz crystal (Piezo-electric)
Cobalt	Rare earths
Columbium	Rutile-brookite
Corundum	Selenium
Diamond (industrial)	Silver
Fluorspar	Sulfur
Gold	Talc (block steatite)
Graphite (crucible flake)	Tantalum
Iron ore	Tellurium
	Thorium
Kyanite (strategic)	Tin
Manganese	Uranium

The contribution of the government may not exceed $250,000 for any single contract, which may run about two years. Repayment of funds advanced by the government is made by a royalty on the production in the amount of 5 percent of the gross proceeds from the property involved in the project; if there can be no production from the project, then there is no obligation to repay.

The functions of the OME were transferred to the U.S. Geological Survey in 1965.

Small Business Administration.—The SBA is an independent, permanent agency established by Congress to advise and assist the nation's small businesses.

SBA loans may be as participating loans, that is, the SBA will cooperate with banks or other lending agencies in the vicinity of the small business by providing a certain fixed percentage (maximum, 90 percent) of the loan. Where no such participation is available, a loan request may be negotiated directly with SBA. To qualify for an SBA loan, a business must be independently owned and operated and must not be dominant in its field. The small business must be unable to obtain needed funds from private sources on reasonable terms. The applicant must be of good character, and must prove his ability to operate the business successfully, as well as have enough capital in the business so that with the loan assistance, he will be able to operate on a sound financial basis. The past earnings record of the business, together with reasonable estimates of future prospects, must indicate the ability of the business to repay the loan out of earnings. An application for an SBA loan requires the usual statements concerning the financial soundness of the business: balance sheets, analyses of surplus, and income statements for recent years. In addition, a description of collateral is required. Beyond this, the information required of an owner of a small mine should reveal:

1. Description of operation, and if available, reports by a mining engineer or other qualified person.
2. Location: Describe clearly, including relation to improved highways or other means of transportation.
3. Maps showing property boundaries and locations of vein outcrops, roads and other facilities such as hoists, ore bins, and concentrator. Mine maps showing workings, and if possible, longitudinal sections along the vein showing areas stoped, width of vein, and assay of samples of ore to be mined during the proposed operation. If open-pit operation, so state.
4. Leases: If property is leased give date, period of lease, royalties required, and other important information.
5. Ore reserves: Furnish your tonnage and value/ton estimate, or the estimate of a qualified

person, and a list of sample assays with width and length of the ore bodies.

6. Mining methods: Describe.

7. Past production and employment: Show days worked for at least the previous 2 years, shipments, and average employment.

8. Concentration: If mill is operated in connection with the mine, describe, giving list of equipment with tonnage capacity per shift. Furnish sufficient information so ratio of concentration can be computed, assay value of mill heads, concentrates produced, and tailings discarded.

9. Costs: Furnish a record of cost per ton mined and the cost per ton milled for the preceding 2 years. If mine has been idle for any part of the period, show cost of maintaining mine and facilities.

10. Management: Describe the qualifications of the person who will be in charge of the operation.

11. Collateral: List all equipment owned as required in the application. The balance sheet should show clearly your equity in the property and equipment.

SBA loans are generally repayable in regular installments, usually monthly, including interest on the unpaid balance, with maximum maturity time of 10 years.

More detailed information concerning the operations of the Small Business Administration may be obtained by writing:

Small Business Administration
1441 L Street NW
Washington, D.C. 20416

The SBA also publishes a wide range of management and technical publications of value to established or prospective operators of small business. Many of the publications are free and others may be purchased for a small charge from the Government Printing Office. Lists of free and for-sale publications may be obtained from the Washington office of SBA or from any of its field offices.

INSTITUTIONAL FUNDS

When insurance companies, investment banks, and endowments have excess capital that is not producing income, sound investments must be sought wherein the capital may be accumulating interest. This source is often mentioned as a possible source of long-term borrowed capital for mines, but it is difficult to understand how a small mine could qualify as a sound investment in the sense that the term is used by such investors. The requirements imposed by the institutions are just too strict to allow them to consider a small mine of the type for which this booklet is written.

COMMERCIAL BANKS

The role of the commercial bank in providing money secured by mortgages on the property of the individual has been discussed. It is equally applicable to the mortgages on real estate owned by the mining company, if the real estate is of a general or commercial value and can be used for purposes other than mining. As for loans to the mining venture itself, there has been no appreciable activity for several years. There have been loans on stockpiles of ore when the banker could be convinced by an uninterested third party of the value of the stockpile, and if there was a ready market for it so that the loan would be of short duration. There is no evidence, however, that such loans have been made for several years. Commercial banks are just not interested in making loans to small mines.

WHAT IT COSTS TO BORROW MONEY

Interest is the compensation allowed by law, or fixed by parties, for the use or forbearance of money, or as damages for its retention. When money is borrowed for any purpose, it must be true that the money will make more for the borrower than he has to pay in interest. For that assurance, the borrower must know what he is paying for the money that he borrows.

Legal interest is any rate of interest, prescribed by the laws of the state, that will prevail in the absence of a special agreement between parties. Lawful interest is interest that does not exceed the rate fixed by statute as being the maximum that can be contracted for.

As one example, let it be supposed that Mr. A borrows $1,000 from his friend. He gives a note stating that he will repay the loan in 1 year with interest at the rate of 6 percent per annum. Mr. A will pay his $\$1,000 + (1,000 \times 0.006 \times 1) = \$1,060$ at the end of the year. In this instance, the interest rate is truly 6 percent.

As a second example, assume that Mr. B borrows $1,000 from Mr. C, but his note allows Mr. C to discount the note, that is, deduct the interest when he lends the money. The other provisions are the same as in the first example. Mr. B actually has the use of only $\$1,000 - \$60 = \$940$, and if he repays $1,000 at the end of the year, Mr. B is actually paying $\$60 \div \$940 = 0.0638$ or 6.38 percent.

The third example explains the type of repayment of a loan that is often used by commercial lending agencies. If Mr. D should borrow some money, say $1,000 from such a company for 1 year, he will generally be asked to conform to a repayment schedule. The schedule will be calculated by adding to the amount borrowed, $1,000, the amount of interest for 1 year, $60, and dividing by the number of repayment periods to arrive at the payment schedule. The monthly payment would be 1/12 of $1,060 or $88.33. If one analyzes the actual situation he will come to the conclusion that Mr. D has the use of the full $1,000 for 1 month, 11/12 of the principal for 2 months, 10/12 of the principal for 3 months, etc.; in other words, Mr. D does not have the use of the full $1,000 for the entire year, yet he is paying interest as if he had. The correct calculation would entail the determination of interest on only that money that is actually used and for the time it is used. Thus, at the end of the first month the interest is $\$1,000 \times 0.06 \times 1/12 = \$5$; interest to be paid at the end of the second month would be $(\$1,000 - \$1,000/12) \times 0.06 \times 1/12 = \$4.58$. Interest at the end of each of the succeeding 10 months would be $4.17, $3.75, $3.33, $2.91, $2.50, $2.08, $1.67, $1.25, $0.83, and $0.42, respectively, and the total interest payment should total $32.49 instead of the $60 that is actually charged. Mr. D is actually paying 11.1 percent on the borrowed money. In addition, if the company that lends the money charges for 'carrying charges', 'credit investigation', 'insurance', 'filing fees', or adds anything else to the principal that must be repaid, it is actually padding the interest charges because that for which it is charging extra would be treated as business overhead by any other type of business. The additional charges will boost the interest rate over 12 percent.

As a fourth example, let it be supposed that Mr. E borrows $1,000 to buy some machinery, agrees to repay $100/month until the debt is extinguished. Included in the repayment of $100/month is interest at the rate of 1 percent per month on the unpaid balance. His repayment schedule will be as follows:

	Monthly payment			
Date	Principal	Interest	Total	Balance
1-1-19—				$1,000.00
1-2-19—	$90.00	$10.00	$100.00	910.00
1-3-19—	90.90	9.10	100.00	819.10
1-4-19—	91.81	8.19	100.00	724.29
1-5	92.73	7.27	100.00	634.56
1-6	93.65	6.35	100.00	540.91
1-7	94.59	5.41	100.00	446.32
1-8	95.54	4.46	100.00	350.78
1-9	96.49	3.51	100.00	254.29
1-10	97.46	2.54	100.00	156.83
1-11	98.43	1.57	100.00	58.40
1-12	58.40	0.58	58.98	00.00

An interest rate of 1 percent per month on unpaid balance is actually the same as a rate of 12 percent per year, there being a slight difference in total payments because of the method of breaking up the payments in monthly installments.

Mortgage repayment schedules are calculated in much the same manner. Suppose, as a fifth example, that Mr. F borrows $10,000 on a piece of property. The mortgage contract calls for him to repay at the rate of $100/month with interest at 6 percent. At the end of the first month, after Mr. F has had the full use of the money for the month, he presents his $100 as the monthly payment. The recipient of the payment will figure the simple interest on the $\$10,000{:}\$10,000 \times 0.06 \times 1/12 = \$50$, then, deducting the $50 interest charge from the payment, he will apply the remaining $50 to the reduction of the principal. When the second payment is made, the monthly interest is computed to be $\$9,950 \times 0.06 \times 1/12 = \$49.75$, and the reduction of the principal will be $50.25.

It is well to put a little thought into the details of any contract in which interest is involved, in order to be fully aware of the total cost of the borrowed money.

AN EXAMPLE OF THE USE OF BORROWED FUNDS

An unusual case of the extremely successful utilization of credit was reported in a national magazine.* It told how a mining man by the name of Walter Seibert of New York used his credit to expand the operation of a fluorspar mine from 1932 until the time of the writing (1952). It seems that when the mine was discovered, Seibert had $6,000 of his own savings and that he was able to borrow $20,000 from friends with which to open the mine. It was the time of the depression and some of the people in the vicinity had no work, so it was easy to induce them to work on the condition that they would be paid when the ore was sold. Seibert then induced the local merchants to advance food and clothing to the miners until they should be paid their wages. After the first fluorspar was sold, the miners and merchants were paid, and the business prospered. In 1935, when the demand for his product gave him the confidence necessary to expand, he borrowed money at 24 percent, then after expansion and after having established a record of shipments, he was allowed to borrow additional money on demand notes secured by ore in shipment. By this time, the revolving credit he was using amounted to $475,000.

The ore body Seibert had discovered turned out to be the second largest then known in the world, and by the time of World War II, demand for fluorspar exceeded the supply. Wartime emergencies made it easy for him to obtain government money through the various government agencies, and combinations of loans, assistance programs, and purchase guarantees enabled Seibert to increase his production to 50,000 tons/year at a guaranteed price of $65/ton.

After all of that borrowing and financial manipulation, Seibert still owned 82 percent of the company.

One question that all who follow the fascinating game of mining will ask, "Didn't Lady Luck have a little bit to do with it?"

*Mining on credit: **Fortune**, v. 46, no. 5, Nov. 1952, p. 236.

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CHAPTER 12 — LAND USE AND ENVIRONMENTAL REGULATIONS

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INTRODUCTION

The United States is one of the few countries in which the vested right to control land for the development of natural resources has been opened to the general populace. The original act giving a citizen the right to stake a mineral lode claim is known as the Mining Law of 1872. It continues to be the underlying authority in mineral-deposit exploitation. Through modification and addition, however, it is only one of the laws with which the present-day miner must comply in his development of a property. Other laws now in effect restrict the miner to development of the natural resources without exploitation of the land, though the laws in no way limit him in the justifiable development of a property.

Mineral commodities that may be developed by an individual have been divided into three groups. Depending on its classification, the commodity developed is treated in one of these ways. These general groupings and means of development are as follows:

1. Locatable minerals; both metallic and nonmetallic (e.g., gold, silver, lead, copper), are located and developed according to the general mining law.
2. Salable minerals (also called 'common variety minerals'); commodities such as sand, gravel, stone, pumice, cinders, clay, and petrified wood, which may be purchased from the U.S. government under the Materials Sale Act of 1947.
3. Leasable minerals; mineral commodities and fuels such as oil, coal, oil shale, potash, sulfur, sodium, asphalt, and phosphate, are leased from the U.S. government.

In this section we will discuss the laws pertaining to locatable minerals, which are those commodities of sufficient value to interest the small-mine operator. Included in this discussion are descriptions of the authority by which land is claimed, the rights of the claimant and of the U.S. government, and the effect of recent additions to the general mining laws. In a later section of this chapter, we will briefly outline the procedures in dealing with leasable and salable minerals.

GENERAL MINING LAWS

The collection of federal statutes and regulations dealing with mining activities is referred to collectively as the U.S. Mining Laws. These direct references along with revisions and numerous court decisions are the body of legal control with which the small-mine operator must deal in his formal staking and development of a mining property. Much of the statutory control was developed in response to the early gold mining activity in the western United States and is referred to as early as 1864 in communications of the U.S. Supreme Court. Thereafter, a succession of laws outlined the claiming procedures, the lands accessible for claiming, and the regulatory control of these activities. The following is a brief account of these acts.

1. The first control of mining appeared in a single mining act passed in 1866.
2. A more comprehensive act was passed May 10, 1872, and is still the backbone of current mining law. Its principal concern was the lode claim, and it was generally thought of as concerning metallic minerals of relatively high value.
3. In 1892, lands valued for the building stone they contained were made subject to the mining laws.
4. In an act of February 20, 1920, lands valued for coal, phosphate, sodium, oil, oil shale, and gas were made subject to leasing.
5. In an act of July 31, 1947, the Mineral Materials Act, certain mineral materials from public domain lands were made subject to sale by the Secretary of the Interior.
6. In an act dated July 23, 1955, the Secretary of Agriculture was given similar authority for land under his jurisdiction. Other aspects of this act were (a) to redefine the salable mineral materials, (b) to limit the use of mining claims to mining activities, (c) to give the government the right of surface management, and (d) to set up a procedure for making the surface use and management requirements applicable to older nonpatented claims.
7. In the Environmental Policy Act of 1969, the U.S. Forest Service was given the authority as a land manager to require that no unreasonable damage of surface resources would result from any activity.
8. The act of December 24, 1970, the Geothermal Steam Act, provided for leasing of lands valued for their geothermal potential

in similar fashion to the lands controlled by the act of 1920. Leasing laws are administered by the U.S. Bureau of Land Management and the U.S. Geological Survey, both within the Department of the Interior.

In summary, the U.S. Mining Laws provide a means for the individual to establish possession of tracts of land valued for their included mineral deposits. The possessory interest was made subject to certain value requirements and could lead to a title in fee simple upon patent. The Bureau of Land Management is responsible for administering this policy, along with limited participation by the Forest Service.

Although the Mining Laws provided the mechanism by which the individual could obtain an interest in mineral lands, other codes limited or determined the specific lands that could be acquired. As an example, two laws were particularly significant in this regard.

1. The Act of March 3, 1891, authorized the President to reserve certain public lands for the National Forests.
2. The Act of June 4, 1897, provided that lands in these forest reservations were subject to the Mining Laws of 1872 and therefore could be exploited. This Act provided regulatory control by the Secretary of the Interior, which was subsequently changed to the Secretary of Agriculture by an act in 1905.

In similar fashion, individual congressional acts have withdrawn various tracts from the public lands subject to minerals exploitation. The result is that the small-mine operator may now claim lands for mineral development only in the remaining public domain not subject to these withdrawals.

As of June 30, 1970, the federal government owned more than 760 million acres of land. The largest part of this land (475 million acres) is controlled by the Bureau of Land Management, which is responsible for maintaining accurate records of public land. The Forest Service controls 187 million acres in the National Forest system. Both agencies are committed to administer these lands under the concept of multiple use, a policy stated in the act of 1955, which provides for the use of public lands for grazing, timber, recreation, mining, watersheds, and wildlife to achieve the maximum benefit to the public.

Other public lands are administered by various agencies, including the U.S. Fish and Wildlife Service, the U.S. Park Service, the U.S. Army, the Bureau of Reclamation, the U.S. Air Force, the Corps of Engineers, the Bureau of Indian Affairs, the U.S. Navy, and the Atomic Energy Commission (ERDA).

Until 1957, the administration of all claimed lands was within the purview of the Bureau of Land Management. In that year, an agreement was reached to allow Forest Service examiners to administer the mining laws on National Forest System lands.

In 1974, after public discussion and significant revision, the Forest Service published rules of conduct for the mining industry designed to aid in the task of multiple-use administration. The rules were the first attempt by a federal agency to allow full access to public lands for minerals activities while ensuring that such access was reasonable in competing with other activities for the use of that same land.

RIGHTS AND OBLIGATIONS OF THE CLAIMANT AND SOVEREIGNS

The General Mining Laws provide certain privileges to the claimant or prospector if he abides by the rules set out in these laws. Four requirements or conditions must be met, after which he is entitled to exclusive possession of a claim for mining purposes. These conditions are as follows:

1. A valuable deposit of a locatable mineral must be discovered on public land that is subject to the mining laws.
2. A claim must be located on the valuable deposit.
3. The claim must be identified and monumented or marked as required by state law.
4. $100 worth of work must be performed for or on the claim each year.

In addition to the temporary form of possession provided by the act of lode claiming, a claimant may obtain free and clear title to the land by applying to the local Land Office for a patent. Along with this application he must prove that he has made a valid discovery of valuable mineral, that he has made improvements to the property totaling $500, and that these will facilitate mining, and if the application is approved, he must pay a fee of $5 per acre for the land patented.

The aforementioned provisions are set forth in the General Mining Laws of May 10, 1872, but court decisions have augmented and clarified precisely the right of the claimant. For example, the right of a prospector to possession prior to discovery is extended against another as long as he is in "diligent search of minerals" and as long as his occupancy is continuous and uninterrupted (52 L.D. 426). Since the passage of the Multiple-Use Act of 1955, the possession of land during mineral search and before discovery does not allow the right to natural resources and surface use beyond that accorded any other individual not a claimant. In essence, recent court cases have given the prospector or small-mine operator the right of possession before discovery as long as his occupancy of the land is continuous, but until a discovery is made, he does not have any special right to the use of the surface or surface resources beyond the right that any other person would have.

Upon location of a valid mining claim, the miner acquires possessory title against all individuals, including the U.S. government. This title can be lost only if (a) the claim is abandoned, (b) the claim is relocated after it has been forfeited, (c) the minerals constituting the discovery are exhausted (i.e., by production), or (d) eminent domain condemnation proceedings against the claim are successful. Otherwise, the claimant has the right to pursue his development of the mineral resources in a manner consistent with the Multiple-Use Act and in accordance with the mineral potential of the property.

RIGHTS OF THE INDIVIDUAL

The rights of the individual on a located claim depend on when the claim was declared valid in the eyes of the government and with respect to the Multiple-Use Act. The following is a list of claimant rights for the claim declared valid subsequent to July 23, 1955:

1. Occupancy and use of claim as required for mining purposes.
2. Ingress and egress and construction of roads and improvements necessary for mining and specifically under prescribed rules and regulations of the cognizant government authority.
3. Cutting of timber from the claim specifically for mining purposes.
4. Grazing within the claim of animals used in the mining operation or for supplying food consumed in the mining operation.
5. Selling or disposing of locatable minerals from the claim.
6. Refusal to allow the United States to dispose of common variety mineral materials.
7. Application for and receipt of patent upon proper application and satisfaction of patent requirements.

In addition, the Forest Service recognizes two other provisions necessary in special land situations. Timber may be removed from a claim for cutting into lumber if a like kind and amount is then used in the mining activity. This allows the miner to obtain lumber in a form more suited to use, which could be prepared only with difficulty on the claim. To allow the miner the use of timber included in prior timber sales, the Forest Service has allowed the replacement of this stumpage from the nearest timber ready for harvest.

RIGHTS OF THE GOVERNMENT

The rights of the United States regarding the mining claim are of two types. First, the government has some rights by virtue of its sovereignty to absolute title to all lands. This right, in the case of mining claims, has been made subject to laws and court interpretations, as described above, which allow possessory title to be obtained by the individual upon compliance with these laws. Also described in these laws is the delegation of land control to various agencies, the most important of which are the Bureau of Land Management and the Forest Service.

The fundamental intent of the United States in maintaining the mineral lands is to recognize them as a valuable mineral estate, which must be protected against unreasonable waste and unlawful or unsanctioned use. Consistent with this intent, it reserves the right of control; for instance, to control infestations extant in the forests, to control patterns of erosion locally inconsistent with best land use, and in short, to manage the use of the surface in the nation's best interest. The right of access for such management purposes is also reserved.

In addition, the United States has an obligation to manage the use of its lands consistent with the rules and regulations provided in the delegation of land-use authority. This obligation includes the control of unwarranted occupancy, unsanctioned or wasteful use of resources, and the use of claimed land for nonmining activities. Such recourse is through legal redress of the individual. In contrast, recourse in the first case is through assertion, with no discretion on the part of a claimant. The intent in both cases is to allow maximum use of the located mineral materials while allowing the complementary use of the claimed land for other, noninterfering purposes.

RIGHTS OF THE STATES

The rights of the states are those delegated by the United States and include both those as a sovereign and those resulting from the legal implications of the mining laws. The most direct control delegated is the requirement of claim identification provided in the 1872 Act.

LAND USE

The right of a miner to use land included within his claim has changed since the passage of the original Mining Law of 1872. The original intent of the law was to provide the resources of the land for unrestricted use in developing the locatable commodity. In this development, the miner had only to fulfill the obligations necessary to validate the claim and he was free to proceed in development. Because of the sparsity of population and the general feeling that the geosystems and ecosystems were sufficiently regenerating to withstand the miners' intrusion, concern for the overall well-being of the environment and the conservation of the various resources did not exist. Slowly, however, it became obvious that these resources should be managed to obviate their rapid depletion or degradation. Moreover, by the early 1950's approximately 200,000 lode claims existed in the United States. These claims constituted a sizable reserve of many nonmineral commodities over which the government had no control. Those regenerating resources such as timber and grazing were subject to abuses that clearly could be avoided with proper management.

On July 23, 1955, an act called the Multiple-Use Act was approved by President Eisenhower and became Public Law 167. The intent of this act was to allow government agencies to administer the public lands and to manage the surface resources on valid mining claims without interfering with the activities of mineral development. The act was not intended to alter the activities of the miner, except those unrelated to mineral production or those in which his activities would be to the detriment of others. A miner can still locate claims and develop the mineral resources. He can patent a valid claim just as before, and when he obtains patent, his ownership of the mineral and surface resources is not less than under the original law. A discovery cannot be based on the location of common-variety mineral commodities such as sand, gravel, or clay, however.

The Act specifies that on claims filed after July 23, 1955, the miner may use his claim for prospecting, mining, or processing, and other directly related operations, but not for any other purpose prior to patent. The miner is allowed to cut timber for his operation and to clear timber to facilitate his mining activities. Prior to patent of his land, however, the United States can "manage and dispose of the vegetative surface resources and manage other surface resources on the claim, provided that such disposal or management does not endanger or materially interfere with the miner's prospecting, mining, or processing operations."

The miner is also required by the Act to comply with established methods of operation and conservation. For example, in cutting trees on his claims the miner has an obligation to proceed in accord with sound principles of forest management in the public interest, thus helping to conserve that timber not required for mining. In return, the Act requires the government to restore to the miner that original stumpage disposed of through timber sales. This timber will come from the nearest available mature source. This provision is intended to provide land support for the miner's activities despite prior government use of the natural resources.

REGULATIONS DIRECTED AT PROBLEMS OF SURFACE DEGRADATION

As a result of the original mining laws, the miner was allowed to develop his properties with no sense of land or resource restriction. By the 1950's it was obvious that unrestricted use of natural resources was not in the best interest of the majority of the people. It remained the intent of the government, however, that mineral commodities be exploited by private entrepreneurs rather than under government intervention or control. It was in areas used jointly for recreation, grazing, lumbering, and mining — that is, in the National Forest — that joint use became a problem. Although the Multiple-Use Act of 1955 allowed for such conjunctive use, it made no attempt to control or police the situation that resulted. Through the National Pollution Act of 1969 and revisions to the Mining Law of 1872, the Forest Service, in 1974, provided rules for the mining industry that would allow development by miners, yet would control large-scale abuses of the land.

The Forest Service published two rules in 1974 that require the following.

1. A notice of Intent to Operate must be filed with the District Ranger.
2. A Plan of Operation must be submitted if significant disturbance of the surface resources is judged imminent.

In complying with these regulations, the miner is generally placed on notice that the Forest Service intends to safeguard the surface resources on any land under its jurisdiction, but nothing in the rules is intended to hinder the miner's progress in developing a discovery or, in fact, to hinder him in exploration. For example, the requirement to submit a plan of operation does not apply to the following:

1. Operations limited to the use of vehicles on public or Forest Service maintained roads.
2. The small-scale mineral collector.
3. Prospecting that does not involve removal or significant disturbance, such as in geochemical or geophysical prospecting.
4. Marking and monumenting of a mining claim.
5. Subsurface operations that will not cause disruption of the surface resources.

In effect, these exclusions allow the miner to prospect at will with nothing more than a notice of intent until such time as a bona fide deposit has been outlined by the customary methods. In addition, the notice of intent is not required when a plan of operation is submitted in lieu of the notice, or when operation will not involve the use of mechanical earthmoving equipment or the cutting of trees.

If the notice of intent or the probable course of operations suggests a significant surface disruption, a plan of operations is required. This plan will contain the following:

1. Name and legal mailing address of the operators or claimants and their lessees, assigns, or designees.
2. A map or sketch showing (a) the location of proposed operations, (b) existing and pro-

posed roads or access routes to be used, and (c) the approximate location of surface resources to be disturbed.

3. Information sufficient to identify (a) the type of operation to be conducted, (b) the type and standard of existing or proposed roads or access routes, (c) the means of transportation used or to be used, (d) the period during which the activities will be conducted, and (e) the methods to be used in guaranteeing environmental protection.

If the planned operation is extensive, the operating plan will include phases of work that can realistically be forecast. Should the work planned be less extensive, the plan would include all major phases of the operation. When an operator expands beyond the initial plan, a modified plan of operation is required.

The plan of operations is intended to advise the Forest Service of the possible use of surface resources. It is the Forest Service's responsibility to judge the extent of use and to prepare an environmental impact statement for this use. Not all plans of operations will require an impact statement, and those that do will present problems of varied complexity. These statements will depend on the nature of the operations (i.e., prospecting, exploration, development, or processing) and on the scope of such operations required (i.e., size of operations, construction required, length of operation, and equipment), which result in varying disturbances to vegetative resources, soil, water, air, and wildlife. The miner must expect to provide the information required for this statement.

From the miner's point of view, it is important to understand the sequence of events surrounding acceptance of the plan of operations. After the plan of operations is submitted, the District Ranger is required to promptly acknowledge its receipt. Thereafter, and within 30 days, an environmental analysis will be made by the Forest Service, and an authorized agent will:

1. notify the operator that the District Ranger has approved the plan of operations, or
2. notify the operator that the type of operations contemplated does not require a plan of operations, or
3. notify the operator of any changes in, or additions to, the plan of operations required to safeguard the environment, or
4. notify the operator that the plan is being reviewed, that more time is required for the analysis (not to exceed an additional 60 days), and the reason that additional time is required, or
5. notify the operator that the plan cannot be approved without a completed environmental impact statement being submitted to the Environmental Quality Council.

Because the time required for approval might extend beyond the duration of a field season, the Forest Service has granted some concessions to accommodate the miner. Sufficient approvals will be granted for that part of the plan of operations necessary to comply with state and federal laws to maintain the properties. Likewise, provisional approvals may be obtained for the modified plan of operations to allow work to continue until a final statement can be prepared. In the review procedures, the claimant may request that counsel be obtained on technical aspects of the proposal.

ENVIRONMENTAL PROTECTION

In the regulations published in 1974, the mine developer is specifically required to conduct all operations in such a manner as to minimize adverse environmental impacts on the National Forest surface resources. Specific areas covered in the revisions are as follows:

1. Air Quality. The operator is required to comply with all applicable federal and state air-quality standards including the requirements of the Clean Air Act.
2. Water Quality. The operator is required to comply with all applicable federal and state water-quality standards including the requirements of the Federal Water Pollution Control Act.
3. Solid Wastes. The operator is required to comply with all federal and state standards for the disposal of solid wastes.
4. Aesthetics. To the extent practicable, the operator shall plan his operation to harmonize with scenic attributes of the area.
5. Fisheries and Wildlife Habitat. The operator shall take all practible measures to prevent disruption of the fisheries and wildlife habitat of the area.
6. Roads. The operator shall construct all roads with adequate drainage and to minimize deleterious effects on soil, water, and other surface resources.
7. Reclamation. After the operations at a property have ceased, the operator will restore the site to prevent and control future damage to on-site and off-site surface resources.

In general, the requirements for environmental protection exhort the operator to plan his activity so as not to degrade other surface resources. In the strict sense, however, this is not possible. Therefore, the requirements, in effect, state that activities must be conducted so as to minimize the effect on natural resources. Clearly, many trade-offs must be considered, and the Forest Service recognizes that the small-mine operator is not particularly well equipped to make the judgment required without some technical help. This is the reason behind the requirements of filing a notice of intent and plan of operations.

In solid-waste control, all garbage, refuse and waste must be removed or treated to minimize impact on the forest surface resources. This extends to such items as tailings, dumpage, and other deleterious materials handled in mining, and the operator is required to arrange and deploy these materials to minimize adverse effects.

The operator is entitled to access to his property, but certain limits are imposed on access improvements. The addition of access-related construction is contingent upon the approval of an operating plan, in writing, which specifies the type and standard of the proposed means of access and which includes a map showing locations, and a description of the means of transportation. The authorizing officer in the Forest Service will require that siting be in the best interests of surface conservation.

When, according to the 1974 regulations, a miner is required to comply with state and federal regulations (e.g., as in abiding by the Water Quality Act), a certificate of approval issued by the cognizant agency will be accepted by the Forest Service District Ranger as proof of compliance.

INTENT TO RECLAIM MINERAL LANDS

Since the enactment of the Multiple-Use Act of 1955, and as more recently specified in the Forest Service regulations of 1974, it is the intent of government to reclaim any lands degraded by previous and proposed activities. The principal rationale is to provide equal potential, rights, and access to prospective users in the future. For this program to be successful, the miner and his employees will be required to operate in the most efficient manner possible and to reclaim or restore the affected area after mining ceases.

At this point it should be understood that reclamation does not mean restoration to the original form of those surface resources disrupted in mining activities. Rather, the form of reclamation is to bring under control the natural processes that have been interrupted and to restore the surface to a natural and productive state. For example, fisheries habitats must be restored to near the original form, but such items as mine dumps and quarries may simply be recontoured to a near-natural surface and reforested.

Among the specific provisions for reclamation, the regulations require the "Upon exhaustion of the mineral deposits or at the earliest practicable time during operation, or within one year of the conclusion of operations, unless a longer time is allowed by the authorized officers, operators shall, where practicable, reclaim the surface disturbed in operations by taking such measures as will prevent or control on-site and off-site damage to the environment and forest surface resources including:

1. Control of erosion and landslides;
2. Control of waste runoff;
3. Isolation, removal, or control of toxic materials;
4. Reshaping and revegetation of disturbed areas, where reasonably practicable; and
5. Rehabilitation of fisheries and wildlife habitat."

The miner is required, within a reasonable time after cessation of operations, to remove all structures, equipment, and other facilities used in the mining activities and to clean up the site of operations. Exceptions must be agreed to by the authorized officer of the Forest Service. On properties that are inactive except for seasonal operations, the miner must file a statement with the District Ranger, which will include the following:

1. Verification of intent to maintain structures, equipment, and other facilities,
2. The expected reopening date, and
3. An estimate of extended duration of operations.

The statement must be filed every year that the property is not reactivated, and the site must be maintained in a safe and neat condition at all times.

After active mining ceases, the miner also has responsibility for the disposition of roads that were used in his operations. Unless otherwise agreed to by the authorized officer, the miner will be required to:

1. Close the roads to normal vehicular traffic;
2. Remove bridges and culverts;
3. Construct cross drains, dips, or water bars in the roads as specified in the operating plan; and
4. Shape the road surface to as near a natural contour as is practicable and stabilize slopes.

To ensure that land is reclaimed after mining activities have ceased, a bond will be required in some cases. Such a bond will be required before approval of the plan of operations, but only when specifically required by the authorized officer. Such bond will be conditioned upon compliance with regulations governing reclamation. In lieu of a bond, the miner may deposit in a federal depository cash or negotiable securities equal to the amount of the required bond. A blanket bond for the nationwide or statewide operations of a company may be maintained. The bond will be conditioned specifically on the estimated cost of stabilizing, rehabilitating, and reclaiming the disturbances resulting from operations. When a portion of the reclamation program, as specified in the plan of operations, has been completed, the bond may be reduced as determined by the authorized officer.

An appeals procedure is specified in the 1974 regulations (252.14). This paragraph sets out the procedure for review and equity if the miner feels that he has been aggrieved by the authorized officer, the regulations of 1974, or by any other official or portion of the law relating to mining operations on land supervised by the Forest Service. The procedure requires that written notice be filed with the authorized officer within 30 days after the date of notification to the miner of the action or decision complained of. Other points relating to the appeal procedure may be reviewed in the above-mentioned code.

COMMON VARIETY MINERAL MATERIALS

In the Multiple-Use Act of July 23, 1955, 'common variety' mineral materials were excluded from location and entry under the general mining laws. As a result, after that date, it was not possible to locate a valid claim using the common variety minerals as the subject of discovery. Since 1955, the courts have attempted to define common variety materials, but not without considerable difficulty.

The term 'common varieties' refers to mineral materials of widespread occurrence and low unit value, which are used in the raw state for common construction. Examples of materials falling in this category are sand and gravel, decomposed granite, fill earth, road metal, and clay used in the manufacture of brick or tile. The material so considered has many substitutes because of its lack of unique character beyond physical properties shared by all similar common materials. In contrast, the uncommon mineral material is one having unique properties that give the substance special value in the marketplace.

In disposing of common variety materials, three situations arise as follows:

1. The claim located prior to July 23, 1955, on which common variety materials were recognized as being valuable.
2. The claim located prior to July 23, 1955, on which common variety materials were not recognized as having value.
3. The claim located after July 23, 1955.

In the first case, the claimant can sell his common variety material with no interference from the government. He is deemed to own it with the right of sale. In Cases 2 and 3, the claimant does not have the right to dispose of common variety materials. These are subject to sale by the government upon waiver of rights to the commodities by the claimant. In both cases, the claimant has the right to control the sale. He has the right to allow or disallow the sale, and only his written consent will allow the government to sell the commodity. The claimant also has the right to use common variety materials in his mining operation and does not need government approval except the required plan of operations.

For an individual to buy common variety materials, he must obtain a use permit from the local office of the Forest Service. Such permit may require payment for the material, and is accompanied by the following regulations:

1. Remove only such material as is designated by the Forest Officer and conduct such operations with due regard to good land management as required by the Forest Officer.
2. Remove no material until payment is made.
3. Leave the area in a condition satisfactory to the Forest Officer.
4. Take all reasonable precautions to prevent and suppress forest fires.
5. Comply with the rules and regulations of the Secretary of Agriculture governing the National Forests.
6. Making a payment or removing material under the permit makes all conditions binding upon the permitee.

LEASABLE MINERAL MATERIALS

The mining and disposing of the leasable mineral materials — soda, potash, phosphate, etc. — are controlled by the Conservation Division of the U.S. Geological Survey. Information regarding permits for exploration and leases for development may be obtained directly from this division, Reston, Virginia. A few aspects of the control and regulation of operations are included below. The supervision and responsibility for controlling the lease operation fall to the Mining Supervisor (a registered professional engineer) and his agents. His responsibilities include the following:

1. Inspection of properties to prevent waste and damage.
2. Enforcement of compliance with regulations and lease terms.
3. Reporting on condition of lands and manner of operations, and making recommendations for property protection.

The regulations with which the lessee must comply in developing a property are very similar to those applying to extraction of locatable minerals, but the Mining Supervisor takes the place of the Forest Supervisor or District Ranger. A permit must be obtained, which is similar to the notice of intent to operate, and a plan of operations must be approved before operations begin. An exploration plan may be required if the operation is extensive. Likewise, a mining plan and details of reclamation procedure may be required. In general, procedures and requirements for opening a mineral lease are similar to those discussed earlier in this chapter.

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