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Underground Mining Systems of Ray Consolidated Copper Co.

BY

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The Property and Location

The Ray Consolidated Copper Co.'s mining property is located on Mineral Creek, 6 miles north of Kelvin, at Ray, Pinal County, Ariz. (Fig. 1).

The mining claims now owned by the company consist of 126 lode claims, comprising 2,144.9 acres, containing at the beginning of operations 82,904,368 tons of 2.19 per cent. copper ore.

General Characteristics of the Orebody

The main orebody is a disseminated deposit in schist and porphyry formed by secondary enrichment. Its existence was proved by churn drilling, and it is at present one of the largest proved copper deposits in the world. The orebody itself covers 205 acres with an average thickness of 121 ft., and occupies a definite belt which has a northwest direction. Its length is approximately 5,000 ft. The width varies, being about 2,000 ft. at the west end and 2,500 ft. at the east, narrowing down irregularly from both ends to a few feet in the center. The thickness of the body varies greatly along the line of lode, ranging from a few feet up to 470 ft. thick.

The ore horizon is not constant, but varies, following in a broad sense the topography. The body in general dips slightly to the northeast, and is broken up by numerous small faults and fractures. The ore-bearing formations, consisting of mineralized schist and mineralized granite porphyry, stand fairly well and offer no difficulty in mining operations.

The bulk of the ore is chalcocite disseminated in schist. In places cupriferous pyrite is closely associated with the chalcocite. The mineralized granite-porphyry formations are contiguous to the ore-bearing schist.

Overlying the orebody is an oxidized zone of leached iron-stained schist, averaging 252 ft. in thickness, termed "capping." The line of

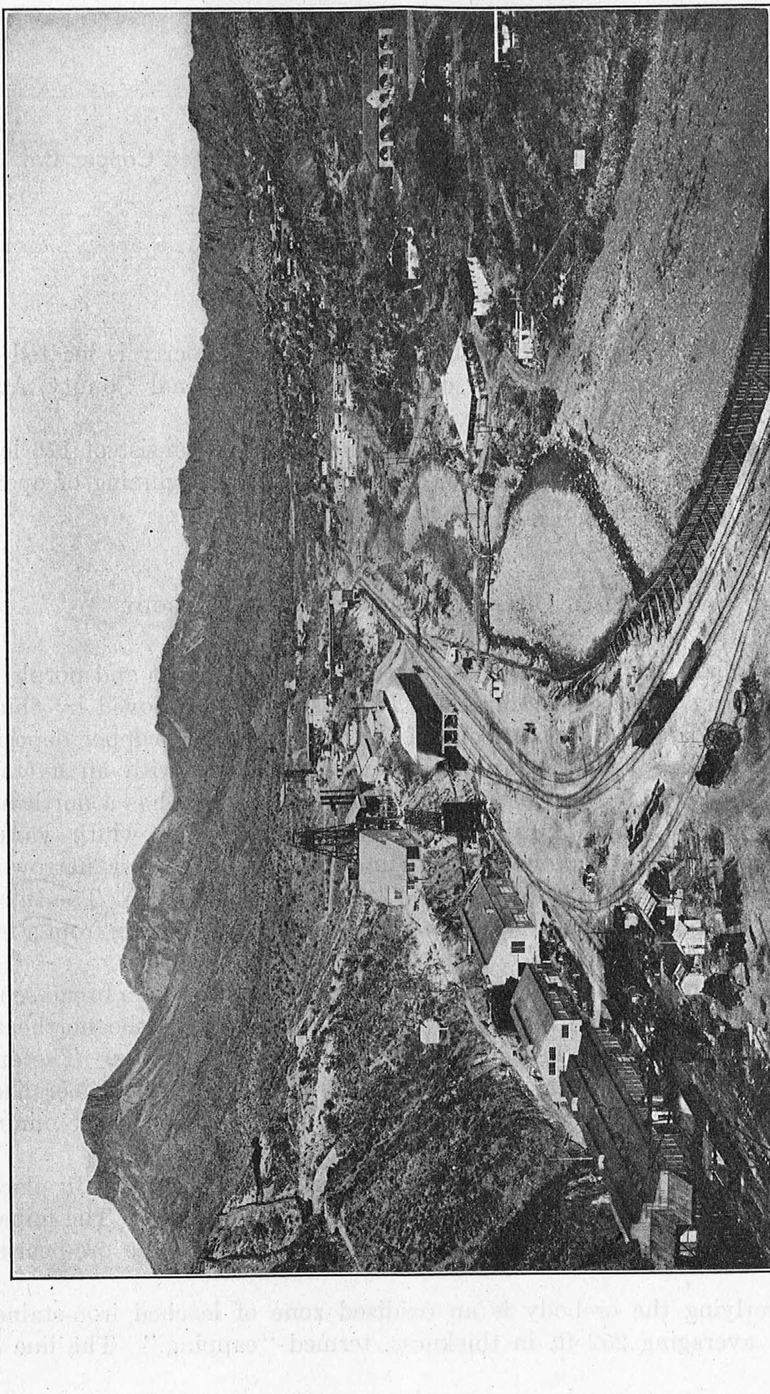


Fig. 1.—Mines of Ray Consolidated Copper Co., Ray, Ariz. Teapot Mountain in the Distance.

demarcation between the ore and capping is easily discerned, owing to the difference in color. In a few places along this line small amounts of the carbonate and silicate of copper occur. Within the orebody a little native copper has been found, and at the base of the oxidized zone small areas contain cuprite.

The foot wall of the ore in many cases is terminated by a diabase intrusion, and in other cases fades off into *protore*, that is, material which by the continuation of the process of natural enrichment might be converted into ore. The ore along the diabase contact is of higher grade than the main orebody.

Determination of Tonnage and Value

In arriving at the tonnage and copper contents of the orebody every precaution was taken to secure accuracy. The developing was done with churn drills and underground drifting and raising. A complete survey of the property was made and the ground covered by a system of north-and-south and east-and-west coördinate lines 200 ft. apart. Churn-drill holes were put down as nearly as possible at the corners of the 200-ft. squares thus blocked out. The sampling was done very carefully. For every 5 ft. of drilling each hole was thoroughly cleaned and the sludge passed through a specially devised sampler. The samples were assayed locally and composites sent to outside laboratories for confirmation. Each drill hole was given a number, and in the office a sheet was kept showing in minute detail the geology, the men doing the work, time required, and assays for every 5 ft. of drilling. Records were also kept to determine the final cost per foot of drilling for each hole.

In determining the tons and assay value of the ore in any block the procedure was as follows: Each 200-ft. block was calculated separately. A survey of each block was made and the horizontal distances between holes determined. With these distances determined the actual area of the rectangle formed by the four holes was computed. After figuring the average for all the assays of that which could be called ore in a hole and multiplying it by the total number of feet of ore, the foot-percentage for the hole was obtained. Proceeding in a like manner the foot-percentage of each hole at the four corners of a block was found. Then after adding all the ore footages (ore in each hole) of the four holes together and dividing this total into the total of all the foot-percentages, the assay value in copper of the total tons of ore in the block was obtained; next by finding the average thickness of the ore in the block (thickness of the ore in each of the four holes added together and divided by four) and multiplying it by the area of the block and dividing by the number of cubic feet to a ton (12½) the total tons in a block was arrived at. Example:

A block having holes 251–249–267–263 for the four corners; area of the rectangle formed by these holes is 84,404 sq. ft.

Number of the Hole	Thickness of Ore, Feet	Average Assay of the Hole, Copper, Per Cent.	Foot-Per Cent.
251	90	1.77	159.30
249	345	1.86	641.70
267	100	2.65	265.00
263	80	2.62	209.60
Totals and averages	615	2.07	1,275.60

Average thickness of the ore in the block $= \frac{615}{4} = 153.75$

$\frac{84,404 \times 153.75}{12.5} = 1,038,169.20$ tons of 2.07 per cent. copper ore

By this method the tonnage and the assay value of each and every block of ore were determined. Then by adding the values for all the separate blocks, the total tonnage and the average assay for the entire orebody were obtained. As a check, the total tonnage was also figured by planimetering cross-sections of the orebody at 200-ft. intervals and computing the number of tons contained therein.

Of the 353 holes drilled to date, only 238 are inside the orebody and considered in calculating the ore tonnage; they represent 106,971 ft. of drilling. It is gratifying to note that all the underground development and prospecting thus far have checked with accuracy the churn-drill results both as to assays and tonnage.

Systems of Mining

Owing to the heavy overburden and the low grade of the ore, caving systems have been devised and adopted which consist in weakening a block of ore by means of a series of shrinkage stopes or "ore-filled rooms." Then after undermining and shattering the remaining pillars the ore is drawn systematically, the capping crushing and settling gradually over it. Throughout all the work at Ray two systems have been used: The sub-level or motor-haulage system, employed in thick uniform blocks of ore; and the hand-tramming system, used in the shallower portions. From the accompanying sketches it will be seen that the method of carrying up the stopes and the manway arrangement are practically the same in both systems, the essential difference being in the method of handling the ore.

The same conditions as exist at Ray had been previously encountered at the Boston mine of the Utah Copper Co., Bingham, Utah, and the systems of mining initiated at that place were subsequently chosen for Ray. In explaining the "Ray systems" now in use it is necessary to go over important changes and steps at Bingham prior to their final adoption at Ray.

SUB-LEVEL OR MOTOR-HAULAGE SYSTEM

At Boston Mine, Utah Copper Co.

During the experimental stages of the system, stopes 20 ft. wide were carried up on 50-ft. centers, leaving pillars 30 ft. wide between stopes, as shown in Figs. 2A to 2D. In all the early operations at Ray as well as at Bingham the main difficulty was with manway connections or entrances to stopes and methods of undermining pillars. Raises at 100-ft. intervals were run up in the centers of alternate pillars and at points every 50 ft. up these raises small crosscuts were run out, from the raise to the edges of the stope on either side, to provide manway connections or entrances to stopes. Men entering a stope passed up through the raises to the first crosscut above the broken muck in the stope. However, this means of entry did not prove satisfactory, as the pillars usually faulted or sloughed before the stope reached capping, cutting off the means of entry.

The next method was to run "manway drifts" parallel to the center line of stopes down the centers of the 30-ft. pillars on sub-levels 50 ft. apart, as shown in Fig. 2C, with crosscuts or entrances to stopes 100 ft. apart. In addition to this means of entry, "pole roads" 100 ft. apart were carried up along one side of a stope, these being located opposite the crosscuts on the sub-level. The pole roads consisted of slabs (that is, segments of round poles) 6 to 8 ft. long, placed horizontally, one directly over the other, 2 to 4 in. apart and in front of a groove or niche in the side wall of a stope. These poles kept the muck from entering the manway. The groove was cut into the wall deep enough to allow a man to pass through with comfort. In order to enter a stope by means of the pole road the men climbed up ladderways in the center of the pillar from the motor level to sub-level 2, then through a small crosscut o the pole road, then up the pole road to whatever level the stope may have reached (see Fig. 2D); or else they could walk down the manway drifts on either sub-level 3, 4, or 5, then through a crosscut to the pole road, and up through it to the stope. Thus it can be seen that in theory the entries were convenient and plentiful. However, such an expensive network of manways did not work out in practice, as the pillar drifts, owing to crushing and faulting of the pillars, in places had to be timbered, thus becoming expensive to maintain. The pole roads also gave trouble, as too much muck had to be blasted into them, in making the niche, to be handled conveniently on sub-level 2, and at times the side walls around the niches broke wide, and expensive blocking and timbering were necessary to keep them open. At Ray, the pole roads were replaced with manways made of frame cribbing, so that the latter difficulty was overcome.

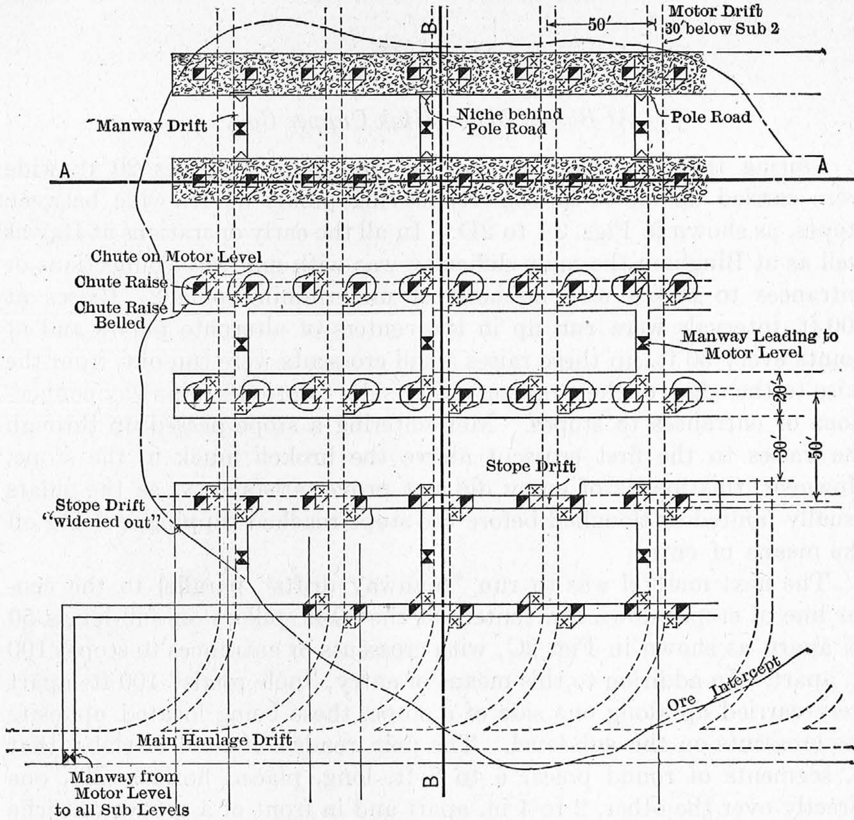


FIG. 2A.—SUB-LEVEL 2. MOTOR-HAULAGE DRIFTS ON MOTOR LEVEL DOTTED.

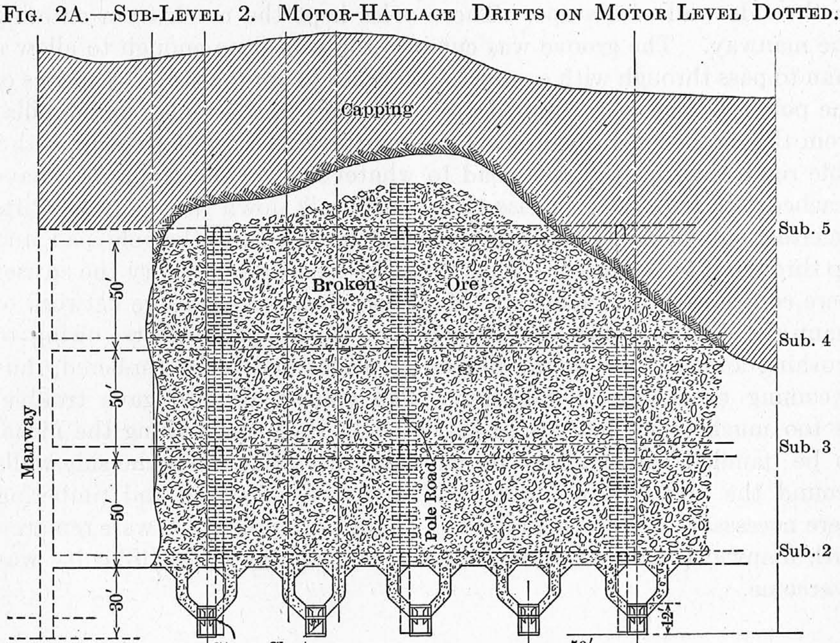


FIG. 2B.—SECTION A–A, SHOWING SUB-LEVELS AND POSITIONS OF POLE ROAD.

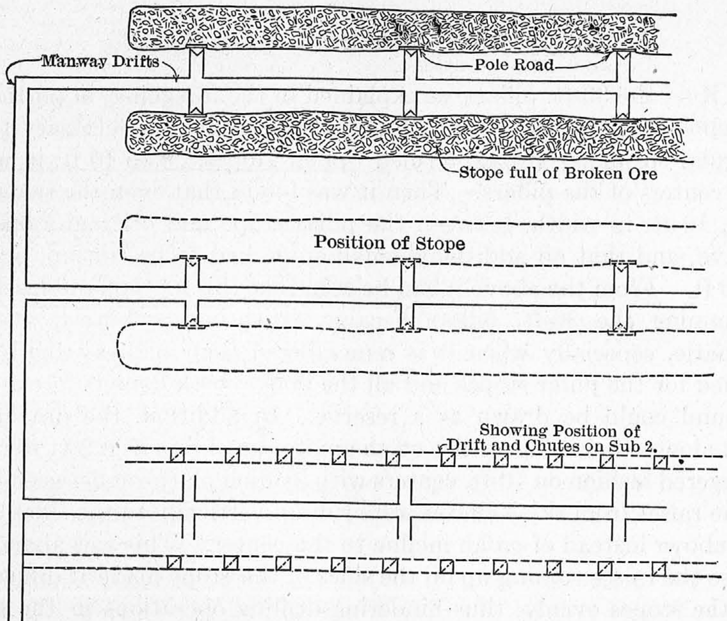


FIG. 2C.—PLAN OF SUB-LEVELS 3, 4, AND 5, SHOWING DEVELOPMENT RELATIVE TO STOPES.

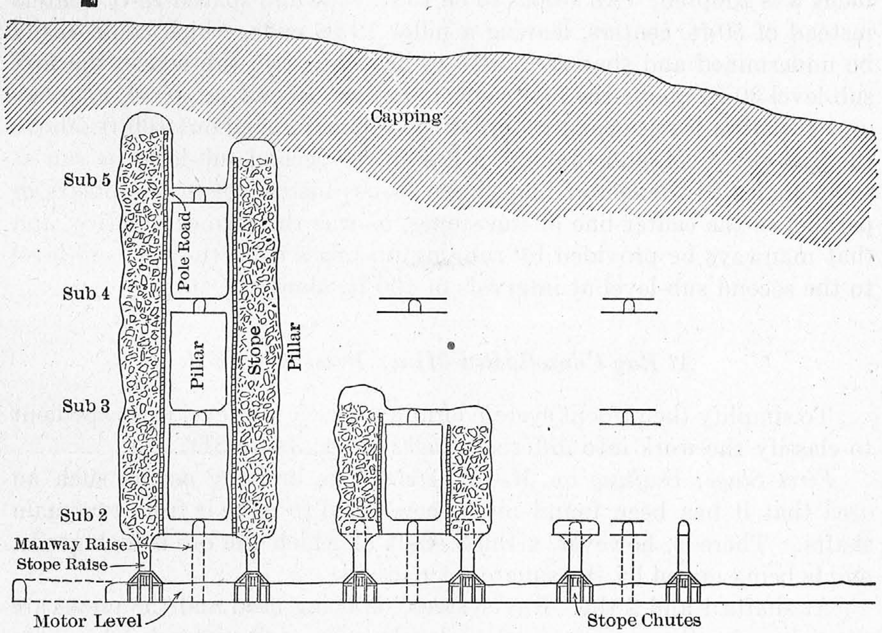


FIG. 2D.—CROSS-SECTION ALONG B–B, FIG. 2A.

FIGS. 2A TO 2D.—SYSTEM OF MINING USED AT THE BOSTON MINE, UTAH COPPER CO., BINGHAM, UTAH, AND IN EARLY OPERATIONS BY RAY CONSOLIDATED, AND FROM WHICH WAS DEVELOPED THE "RAY SYSTEM" OF UNDERGROUND MINING WITH MOTOR HAULAGE.

At Ray Consolidated Mine: Early Method

At Ray, the 30-ft. pillars, as explained in the foregoing, in portions of the orebody, did not crush as was expected, and it was necessary to put up regular shrinkage stopes, termed "pillar stopes," 8 to 10 ft. in width, in the centers of the pillars. Then it was found that even the remaining pillars, 10 ft. in width, between the pillar stope and original stope, did not cave, and that an additional small stope had to be run up, perhaps 8 to 10 ft. From the above it can be seen that this method of blasting or undermining the 30-ft. pillars became expensive, awkward, and unsystematic, especially when it is remembered that manways had to be provided for the pillar stopes and all the above work done before a block of ground could be drawn as a reserve. In addition, the drawing-off chutes along the haulage drifts on the motor level (see Fig. 2A) were put in staggered fashion on 10-ft. centers with loading platform between them, and the raises from these chutes were run up vertically to the sides of the stope above instead of on an incline to the center. This was abandoned because the raises coming up on the sides of the stope made it difficult to draw the stopes evenly, thus hindering drilling operations in the stopes themselves.

In order to overcome these difficulties a decided change in the arrangement was adopted: All stopes to be 15 ft. wide and spaced 25-ft. centers instead of 50-ft. centers, leaving a pillar 10 ft. wide, which could easily be undermined and shattered; also to have but two sub-levels; the first sub-level 30 ft. above the motor level, and the second sub-level, manway or ventilation level, near the top of the orebody, or about 100 ft. above the first sub-level, and that the drifts on the second sub-level be run at right angles to the center line of the stopes instead of in the pillars or parallel to the center line of the stopes, as was the former practice, and that manways be provided by running up raises from the first sub-level to the second sub-level at intervals of 100 ft. along the stope.

At Ray Consolidated Mine: Present Method

To simplify the present system of mining with sub-level it is expedient to classify the work into different stages (Figs. 3A to 3D).

First Stage: Drifting on Motor Level.—The orebody covers such an area that it has been found more economical to mine it from two main shafts. There is, however, a third shaft at which the ore is high grade, and is being mined by the square-set method.

At shafts 1 and 2 the "Ray system" is being used and the mines are opened up by three motor-haulage levels. On each motor level a main drift (double track, 30-in. gage) with two compartments (each 7 ft. wide, 8 ft. high, timbered with 12 by 12 in. posts, 12 by 14 in. caps, 6 by 12 in. sills, and 10 by 12 in. collar braces 4 ft. 2 in. long so as to place posts on 5-ft. centers) runs out from the hoisting shaft for a short distance to provide storage and passageways for trains and then narrows down to a single-track drift which is extended out along one side of the orebody. From this main drift a system of parallel drifts are turned off on a 60-ft. radius curve at intervals of 50 ft. and these are extended entirely through the orebody to a "fringe drift" which follows the ore intercept. Somewhere along the main drift, or one of the parallel drifts, in a convenient place outside the orebody, a "permanent raise" is run up to the sub-levels. Such a raise is usually widened out and cribbed into two compartments (cribbing 6 by 10 in. by 9 ft. long, dapped 1½ in. deep and 6 in. back on the narrow sides of both ends and also in center for spreaders 6 by 10 in. by 5 ft. long. Spreaders are all dapped 1½ in. deep and 6 in. back on the narrow sides of both ends). One compartment is used as a manway (size 3 ft. 6 in. by 4 ft.), the other (size 4 ft. by 4 ft.) for hoisting supplies such as steel, pipe, hose, cribbing, powder, etc., for the stopes.

Second Stage: Chute Building on Motor Level.—Usually as the parallel motor drifts are driven they are timbered within the ore limits with 12 by 12 in. by 7 ft. 6 in. posts, dapped 1 in. deep on three sides at upper end to receive the cap and collar braces and 1 in. deep on drift side of bottom end to receive sill. Caps are 8 by 12 in., 9 ft. long, dapped 1 in. deep on all four sides at the ends and 11 in. back on three sides and 8 in. on the fourth or top side (on one of the 12-in. faces) to receive pony posts. The cap rests flatwise on the posts. Sills are 6 by 12 in. by 9 ft. long dapped 11 in. back and 1 in. deep on the upper side of both ends to receive posts. Collar braces are 8 by 12 in. by 4 ft. 2 in. long, framed 1 in. deep and 1 in. back on one 8-in. face at the ends to fit in with cap. The caps and collar braces are made of light timber to be subsequently protected with "pony sets" (Fig. 4).

Outside the ore intercept 12 by 14 in. timbers are used for caps and 10 by 12 in. for collar braces.

Within the ore limits below an area which is to be stoped, pony sets are erected on top of all drift sets and are made up of 8 by 12 in. by 5 ft. posts dapped 1 in. deep and 1 in. back on three sides at the ends; 12 by 14 in. caps 9 ft. long, framed 1 in. deep and 7 in. back on three sides of both ends to receive posts and collar braces, are used. Collar braces are 8 by 14 in. by 4 ft. 2 in. long, dapped 1 in. deep and 1 in. back on the drift side of both ends to fit in with the cap, thus spacing drift sets on 5-ft. centers.

In heavy ground a 6 by 12 in. filler block is placed under the cap, and supported in center of cap by 12 by 12 in. angle braces 5 ft. long over all, extending diagonally down to corners formed by pony posts and top of cap of drift set (Fig. 4).

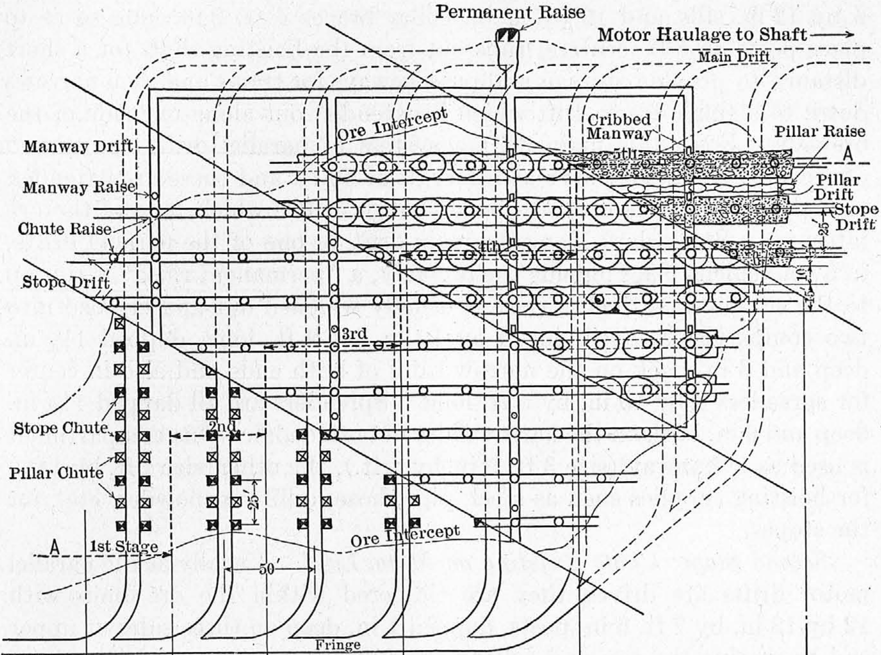


FIG. 3A.—PLAN SHOWING SIX STAGES IN DEVELOPMENT.

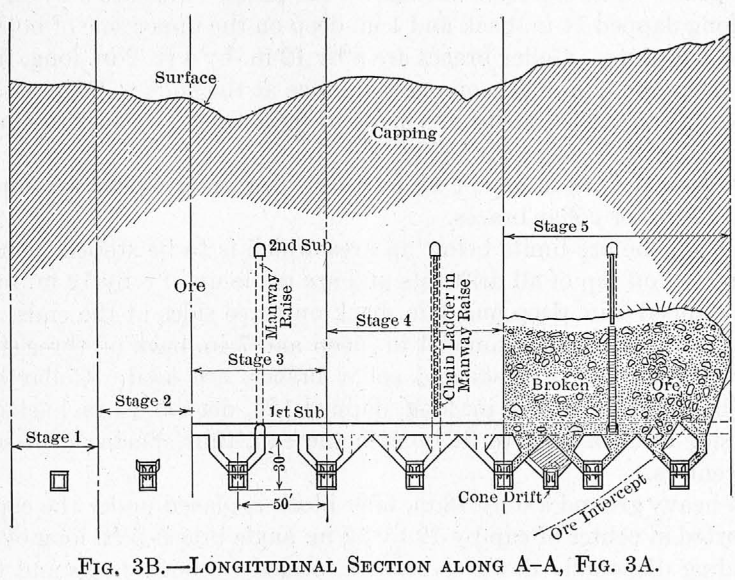


FIG. 3B.—LONGITUDINAL SECTION ALONG A–A, FIG. 3A.

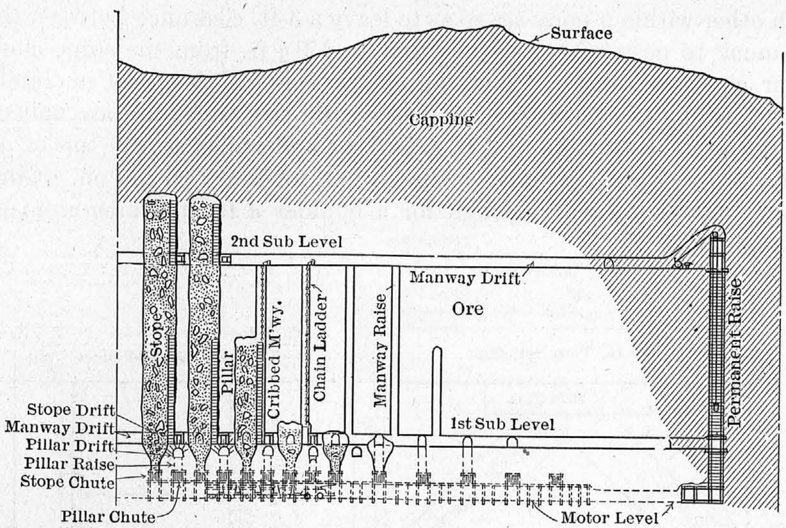
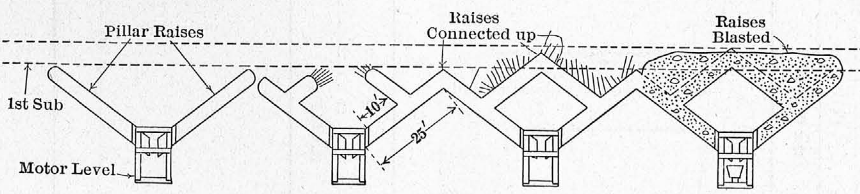
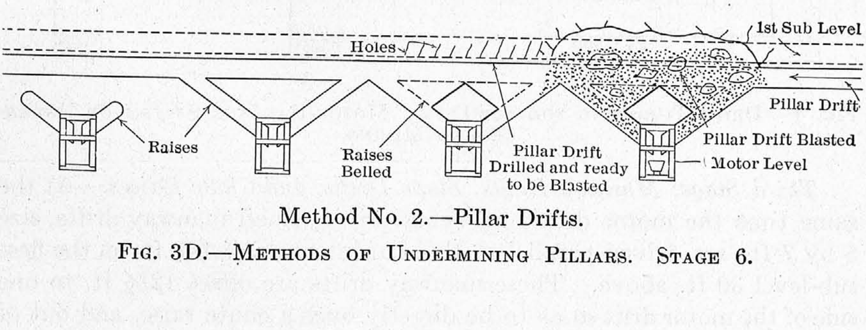


FIG. 3C.—CROSS-SECTION SHOWING SHRINKAGE STOPES AND PILLARS.



Method No. 1.—Pillar Raises.



Method No. 2.—Pillar Drifts.

FIG. 3D.—METHODS OF UNDERMINING PILLARS. STAGE 6.

FIGS. 3A TO 3D.—"RAY SYSTEM" OF MINING. SHRINKAGE STOPES AND PILLAR CAVING WITH SUB-LEVEL AND MOTOR HAULAGE.

At intervals of 25 ft. along the drift, stope chutes are built opposite each other within a pony set so as to leave a 3-ft. clearance between them for muck to pass. Midway between, or 12½ ft. from the stope chutes, pillar chutes are built. The chutes are made of 3 by 10 in. lumber, sides 3 ft. 6 in. long with 60° bevel on the two ends, and are nailed to pony posts. Bottoms are 3 ft. 6 in. long and nailed to the top of drift collar brace so as to have an incline of 30° for muck to run on. Chutes when finished are wide enough for a boulder 3 ft. in diameter to pass through (Fig. 5).

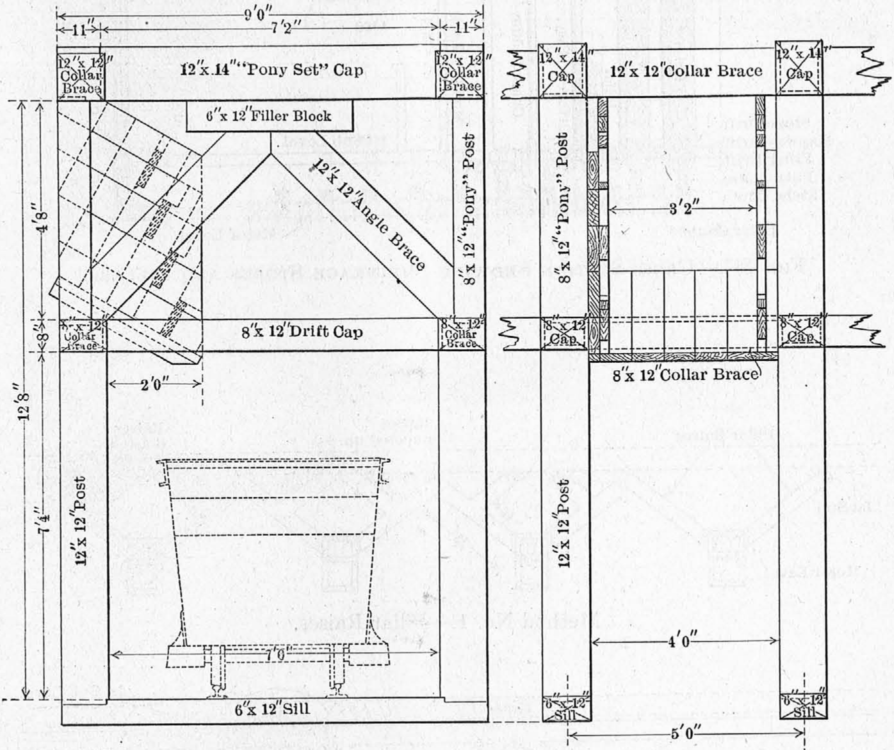


FIG. 4.—DRIFT TIMBERING FOR SUB-LEVEL, MOTOR-HAULAGE SYSTEM OF UNDERGROUND MINING.

Third Stage: Manway Drifts, Stope Drifts, and Chute Raises.—At the same time the motor drifts are being driven, small manway drifts, size 5 by 7 ft., are driven parallel to them at intervals of 100 ft. on the first sub-level 30 ft. above. These manway drifts are offset 12½ ft. to one side of the motor drift so as to be directly over a chute raise, and out of them at right angles are run a series of parallel stope drifts, spaced every 25 ft. over the entire orebody. These stope drifts are placed so as to be directly above stope chutes on the motor level, so that when raises are run up from the stope chutes they break into the stope drifts and become passages through which ore is drawn out into motor cars. The raises are usually 6 ft. in diameter and are run on an incline for 10 ft., then vertically until they strike the stope drift above.

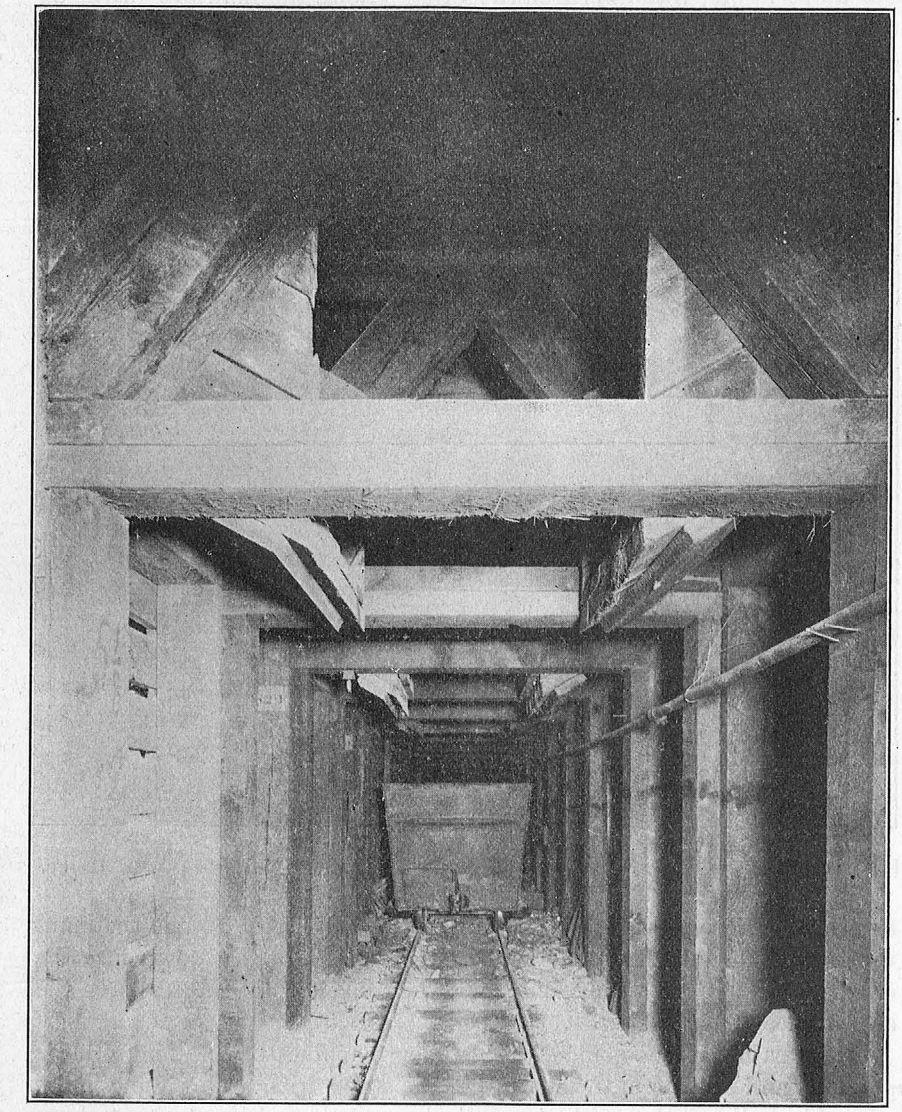


FIG. 5.—MOTOR DRIFT, SUB-LEVEL SYSTEM. SHOWING PONY SET, CHUTES, ANGLE BRACES, AND A 5-TON CAR.

On a second sub-level, which is usually about 100 ft. above the first sub-level, manway drifts are driven parallel to and directly over those driven on the first sub-level. Then later when connections are made they serve for ventilation and passages through which men and supplies enter and leave stopes.

Fourth Stage: Manway Raises, Belling Out Chute Raises, Widening Out Stope Drifts, Building Manway Sets.—Along the manway drifts on the first sub-level, at intervals of 25 ft. and 7½ ft. from the center of each stope drift, manway raises are run up to manway drifts on the second sub-level. Chain ladders are put into these raises so that men may descend or ascend from one sub-level to the other, and later the raises serve

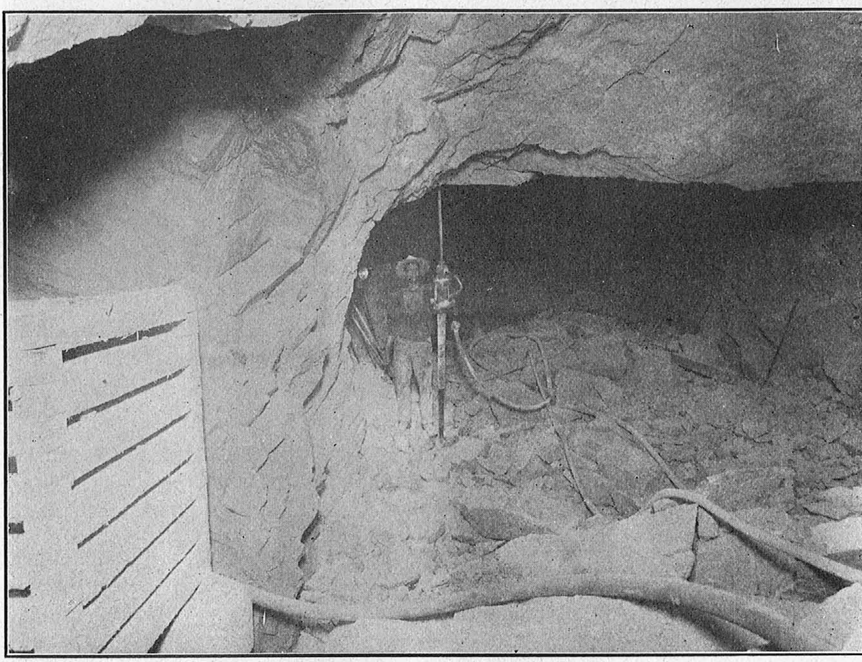


FIG. 6.—INSIDE A STOPE. SHOWING CRIBBED MANWAY BELOW MANWAY RAISE.

as means of access to stopes from the second sub-level. While the manway raises are being run, men with stoper machines go down into the chute raises to "bell" them out, and when finished the chutes have the appearance of funnels or inverted bells.

In starting a stope, men with stoper machines drill a line of holes all along and slanting into the sides of the stope drift. This line of holes when blasted, together with the work done to these drifts during "chute belling," widens them out to 15 ft. so that they are ready to start up as "active stopes."

As soon as the stopes are ready to start upward (Fig. 6), manway sets are erected in the manway drifts on the first sub-level. These sets are built so that the 8 by 8 in. stringers on which the posts stand project out into the stopes, and a 3 by 3 ft. opening, made by cribbing (manway timbers) built up on these stringers, lies directly under a manway raise and serves as an entrance into an active stope from the first sub-level. The manway sets are made of 8 by 8 in. timbers, and the manway cribbing of 4 by 6 in. by 3 ft. 8 in. long, dapped 4 in. back and ¾ in. deep on the narrow side of both ends.

Fifth Stage: Mining Stopes to Capping.—In mining a stope (blasting down the back), two lines of holes, opposite each other, are drilled all along the back on both sides of the stope. The one line is drilled close to the side wall, with the holes slightly toeing into it; the other line, usually placed 4 ft. away from the side wall, is drilled so that the holes incline slightly toward the center of the stope. If the ground is very hard a third line is drilled still nearer the stope center. The machinemen working in the stopes use stoper machines and each man drills from 12 to 18 6-ft. holes per shift. These holes are usually loaded with four sticks of 30 or 40 per cent. powder; 6- and 7-ft. fuses are used, and each man blasts his own holes, going off shift. The oncoming shift draws off through the stope chutes into 5-ton motor cars on the motor level the excess ore, which is usually 33 per cent. of the total broken per round, thus giving the men plenty of headroom to re-drill the back while standing on broken ore.

The manways are built up with cribbing, when necessary, so as always to be open and above the muck. The machinemen in a stope receive air for their machines through a 1¾-in. supply hose dropped down from the second sub-level through each of the manway raises. When a stope has reached a place about midway between the first and second sub-levels, the men naturally descend into the stope from the second sub-level through the manway raises instead of climbing up through the cribbed manways from the first sub-level. The cribbed manways become therefore a needless expense and are covered over the top with 2-in. lagging and left behind.

In hard ground the stopes are carried up 15 to 20 ft. wide, and in soft, "sloughing" ore 10 to 15 ft. wide.

Blacksmith shops are provided underground near the areas being stoped, so that men are quickly supplied with sharp steel and tools (Fig. 7).

Sixth Stage: Undermining Pillars.—After a block of ore has been weakened by a series of stopes the only step remaining in order for the entire block to crush and break is to undermine the pillars. Two methods are now in use:

Method 1: Pillar Raises.—Used in blocks of ore where the ground is hard and the stopes are carried up 15 to 20 ft. wide, leaving narrow pillars which are readily undermined. Starting with the pillar nearest the "fringe drift" on the motor level, raises are run out on flat inclines from each of the chutes for the same pillar in the various drifts until they intersect each other (Fig. 3D, Method 1). Then out of these raises at a distance 10 to 12 ft. from the chutes, raises are run back so as to connect with each other directly over motor drifts. After the raises have been connected up all along a pillar they are widened out, lined with deep holes and blasted so as to undercut the entire pillar completely. Proceeding in a like manner with each consecutive pillar, the whole block is finally undermined.

Method 2: Pillar Drifts.—Used in blocks of ore when the ground is sloughing, badly faulted, and packs, so that for safety to the miners the original stopes had to be carried up narrow, 10 to 15 ft. wide.

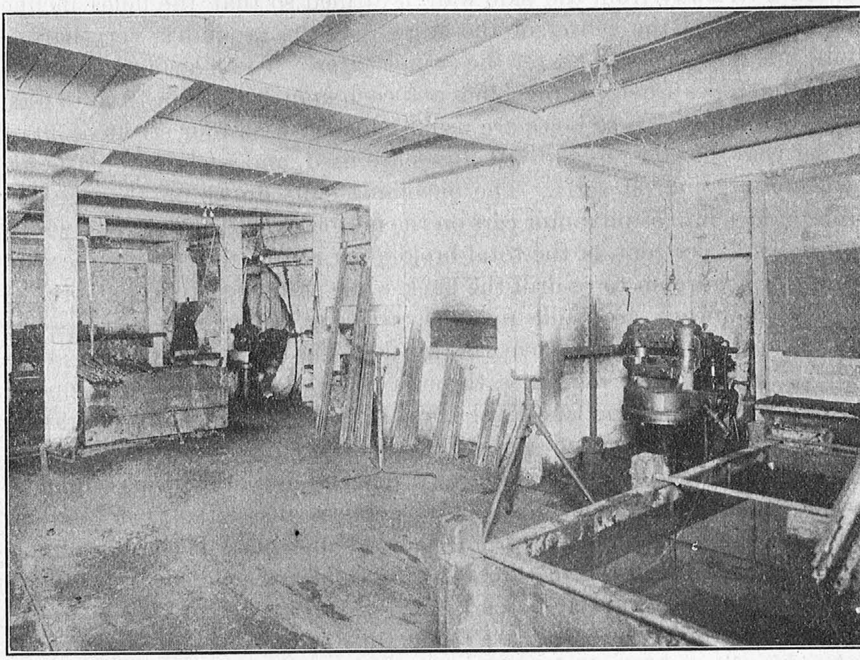


Fig. 7.—Underground Blacksmith Shop. Showing Steel Sharpener to the Right, and Hand Forge to the Left.

In the center of and all along a pillar between two stopes, at a height of 22 ft. above the sill of motor level, small drifts are driven with plugger machines (Fig. 3D, Method 2). Raises from the "pillar chutes" are run up on flat inclines until they intersect the drift. The drifts can be widened out as much as desired with stoper machines, to undercut the pillar. The raises are "belled," and the back of drift filled with deep holes and blasted so as to shatter the pillar completely.

The advantage of Method 2 is that a pillar of any width may be undercut and shattered; however, Method 1 is cheaper, and therefore is used where the pillars are narrow.

Seventh Stage: Reserve Drawing.—In most cases the orebody and capping, especially at No. 1 shaft, are badly shattered and broken up by small fracture seams so that when the pillars in any stoped area are undercut and the ore drawn, the capping directly over the outer edge of the area breaks in a nearly perpendicular plane to the surface.

In areas where the haulage drifts are to be abandoned as soon as all ore has been drawn, the procedure at present is to get the waste on a slight incline dipping toward the fringe drift. This is accomplished by drawing the chutes nearest the fringe more rapidly than those farther away, so that by the time the drifts take weight all ore will have been drawn and the occasional expense of retimbering, when all chutes in an area are drawn evenly, overcome.

An accurate account is kept of the ore drawn from every chute so that the ore remaining in each is always known. Only a few cars are drawn at a time, thus permitting the ore to settle gradually, with capping following after, thereby avoiding as much as possible the intermixing of the two.

For drawing chutes, empty cars are fed by the motorman through the fringe drift into the back ends of the parallel drifts, in which chutes are being drawn. These cars are then one by one taken ahead by a car pusher to the chute from which the ore is to be pulled. A chute blaster or loader stationed on a platform at the base of a pony set then lifts the boards or gates in the chute and allows the ore to run into the car. When a car is loaded a second car pusher shoves it down toward the main drift while his partner is spotting another empty for the chute blaster to load. All drifts are run on ¼ per cent. grade in favor of the load.

As soon as a train (usually 8 to 12 cars) has been loaded and pushed ahead, a motor comes through the main drift into the lateral; the motor helper couples the cars, and the motor then takes the train of cars to the shaft or tipple, where it is dumped, and the empty cars are returned to the back end of whichever drift may be in need of them.

The highest efficiency and best results are obtained when only two car pushers and one chute blaster (car loader) are used in each drift. Recently at the No. 1 shaft, six car pushers, three chute blasters, two machinemen, one mucker, and one chute repairer (timberman), working in four different drifts, loaded 400 motor cars, or an average of 150 tons per man, during a shift of 8 hr.

Machinemen drill and blast any large boulders which may lodge in a chute, also connect over raises preparatory for undermining pillars. The chute repairer replaces any broken chute boards, and makes other small repairs needed after blasting. The only men employed in a reserve-drawing section, other than those mentioned above, are timbermen on general repair work, a car checker, and a boss.

Eighth Stage: Cone Drifting.—After all chutes in a block have been drawn to capping, the next step is to recover the ore below the sub-level in the pillars between the motor drifts. This is done by first driving a small timbered drift parallel to the motor drifts in the centers of the pillars throughout the entire length of the block. Chutes are built opposite each other in every set along the drifts. A small stope extending along and directly over the drift is widened out and carried up to the sill of the first sub-level. Ore is drawn out into small cars (capacity 22 cu. ft.), which are then pushed by hand to a dumping chute, or winze, at the end of drift, where the ore is dumped to the next motor-haulage level below. When all chutes in this center cone drift have been drawn to capping, the small pillars still remaining on either side are taken out by slicing, so that eventually all ore above the sill of the motor-haulage level will have been extracted.

Hand-Tramming System

This system differs from the sub-level method in that the stopes are started immediately above the drift sets and the ore is drawn out into cars of 22 cu. ft. capacity which are pushed by hand to dumping chutes.

At Boston Mine, Utah Copper Co.

Drawing-Off Chutes on One Side of Stope.—In the early experimental stages this method of stoping was very crude, as can be seen from Fig. 8A; on the tramming level a stope drift was run at right angles from a series of parallel drifts which had been spaced 30 ft. centers. The stope drift was widened out to 20 ft. by slabbing off the sides with "water-Leyner" drifters. At intervals of 60 ft. along the stope, pole roads were provided for men and supplies to enter and leave stope. These pole roads were made by building up slabs or round poles in front of niches in the side wall of the stope. At first the excess ore broken by the machinemen was drawn off below by men shoveling it into cars holding 28 cu. ft.; this was soon found to be expensive stoping, so chutes were built in the faces of each drift, and ore then drawn direct from stope through the chutes into cars.

The disadvantages were that only a small tonnage could be obtained, as only one stope could be worked at a time; the stope being drawn on only one side made it difficult for the machinemen to work; cars had to be loaded at the ends instead of at the side, and consequently were continually over-running, necessitating shoveling to clean track after each tram; low final extraction, as ore in far side of stope could not be recovered, and as can be seen from the present Ray method of starting stopes, the work of drifting and slabbing on the sill floor was a waste of time and money, as the void made by this work was refilled with unrecoverable broken ore from the stope.

Drawing-Off Chutes on Both Sides of Stope.—In order to overcome some of these defects the scheme shown in Fig. 8B was adopted. Here the tramming drifts, 60 ft. apart, were run down the centers of the pillars between stopes, and at intervals of 30 ft. crosscuts were turned off from them at right angles to the stope on either side. This arrangement provided chutes 30 ft. apart on both sides and all along each stope, so that the ore in the stope could be drawn down more evenly and a higher final extraction obtained; this also made it possible to work two or more stopes at a time, giving a greater output. However, the stopes were started in much the same way as before in that a small drift was run down the center position of a stope, later slabbed out to 20 ft., or to whatever width it was decided to make the stope, and the stope started direct from the sill floor of the tramming level. The pole roads for manways were run up in much the same way as previously explained. The disadvantages of loading the cars at the end; the poor ventilation in stopes; difficulty with manways; waste of time and labor of slabbing on sill floor before a stope could be started, still continued. Also, by reason of the fact that the crosscuts leading from tramming drifts were directly opposite each other, too large an opening was necessary, so that pillars took weight, making it difficult to keep tramming drifts open. The arrangement of having the chutes along the sides of the stope made it necessary for the machinemen at times to work out in the center where muck was continually falling (sloughing) from the back, and also made it necessary while starting up a stope to shovel the ore along the center, over to the sides above a chute.

Drawing-Off Chutes in Center of Stope.—In the next block of ore, to further reduce difficulties, the tramming drifts were run down the centers of every alternate pillar, thus eliminating one-half of the development work, and instead of turning the crosscuts to the stopes out of them at positions opposite each other they were placed staggered fashion (see Fig. 8C) so that the smallest opening possible was obtained at every point along the tramming drift. The crosscuts were extended in each case beyond the center line of stopes and two chute sets erected in each to provide chutes directly under the stopes instead of at sides. In starting a stope, raises were run up on flat inclines out of each chute, until they intersected, thus forming "hog-backs" between each pair of crosscuts. This method of starting stopes was a decided improvement over the previous procedure, as it eliminated all the expensive drifting and slabbing on the sill floor under a stope, and made it possible to recover all ore broken in a stope. Manways were provided at first in much the same way as in early operations with the sub-level system as previously explained; *i.e.*, raises were run up out of the tramming drifts at spaces

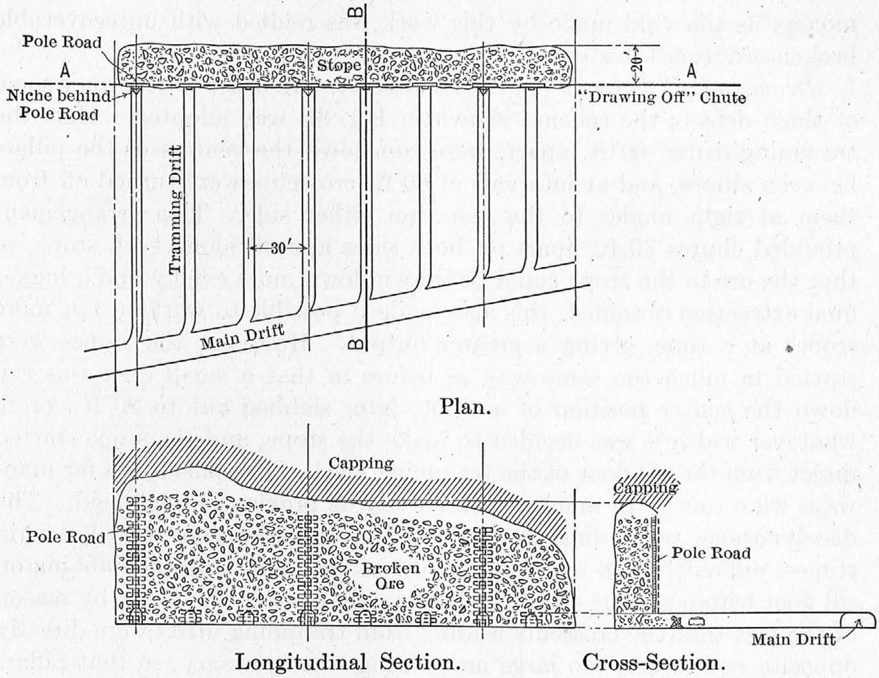


FIG. 8A.—SYSTEM OF MINING AT BOSTON MINE WITH DRAWING-OFF CHUTES ON ONE SIDE OF STOPE.

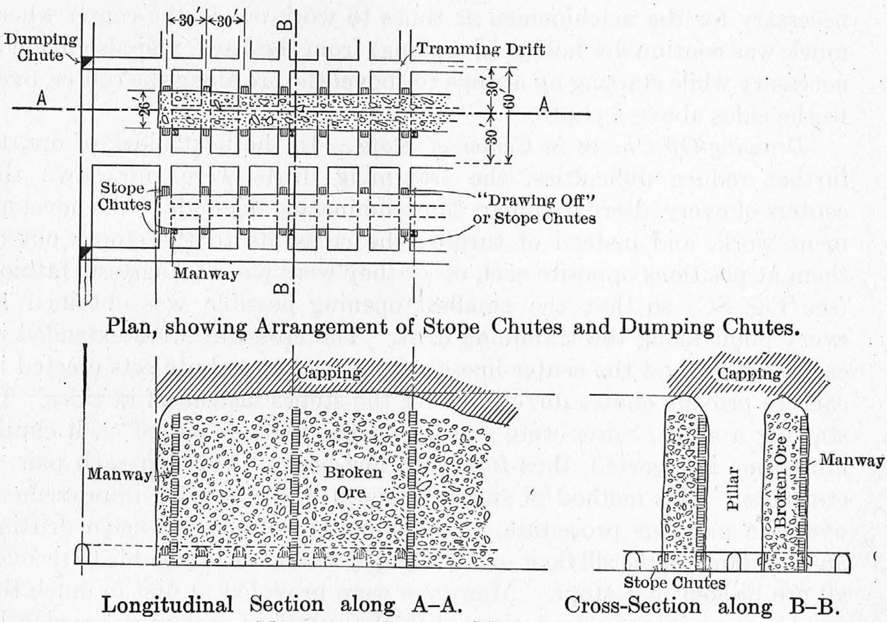


FIG. 8B.—SYSTEM OF MINING AT BOSTON MINE WITH DRAWING-OFF CHUTES ON BOTH SIDES OF STOPE AND TRAMMING DRIFTS IN EVERY PILLAR.

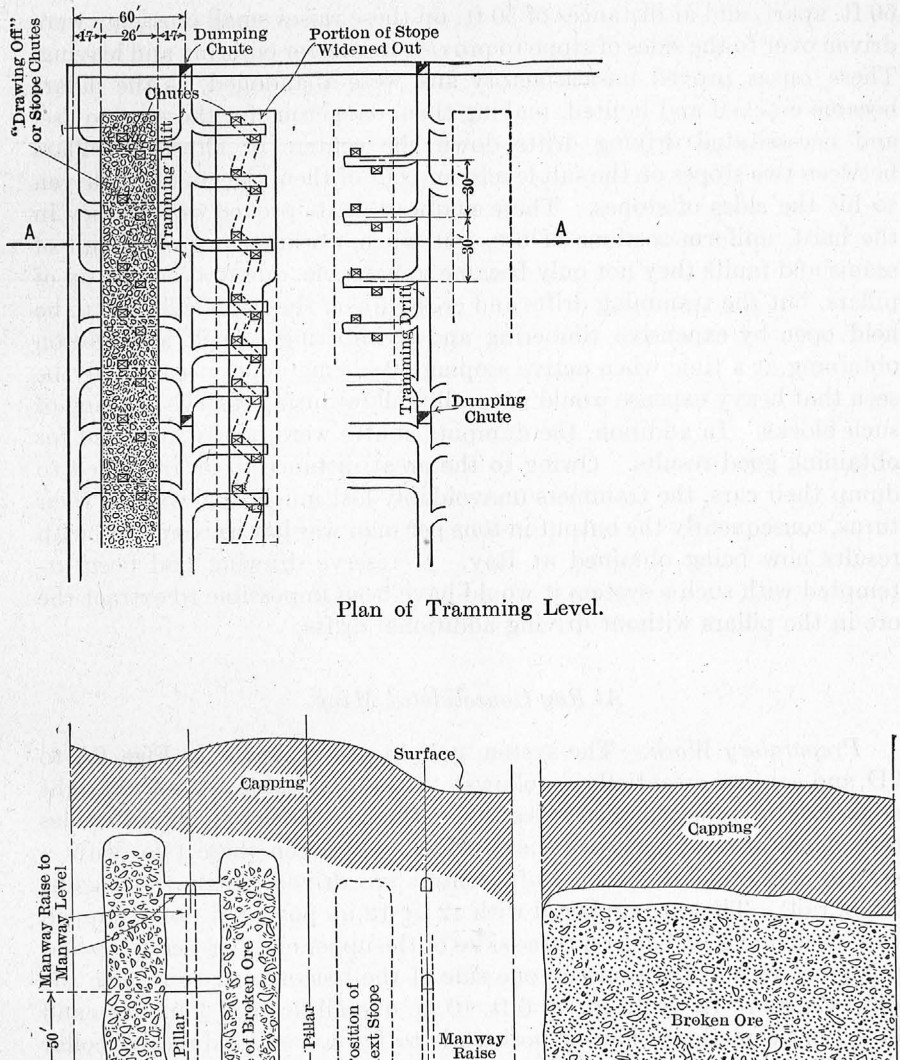


FIG. 8C.—SYSTEM OF MINING AT BOSTON MINE WITH DRAWING-OFF CHUTES IN CENTER OF STOPE AND TRAMMING DRIFTS IN ALTERNATE PILLARS.

60 ft. apart, and at distances of 50 ft. up these raises small crosscuts were driven over to the sides of stope to provide means for entering and leaving. These raises proved unsatisfactory and were abandoned, as the pillars became cracked and faulted, making them dangerous for the men to use, and necessitated driving drifts down the centers of alternate pillars between two stopes on the sub-levels, and out of them the crosscuts driven to hit the sides of stopes. These manway drifts proved satisfactory in the hard, uniform sections of ore, but when working in ground full of seams and faults they not only became impassable, due to breaking up of pillars, but the tramming drifts and crosscuts on the main level had to be held open by expensive timbering and retimbering. Such a condition obtaining at a time when active stoping was being done, it can easily be seen that heavy expense would naturally follow during reserve drawing of such blocks. In addition, the dumping chutes were poorly arranged for obtaining good results. Owing to the great distance to be traversed to dump their cars, the trammers unavoidably lost much time waiting their turns, consequently the output in tons per man was low as compared with results now being obtained at Ray. If reserve drawing had been attempted with such a system it would have been impossible to extract the ore in the pillars without driving additional drifts.

At Ray Consolidated Mine

Preparatory Work.—The system now in use is shown in Figs. 9A to 9D, and consists essentially as follows: All the tramming drifts are at right angles to the stopes, instead of parallel to them. Along two opposite sides of a block of ore fringe drifts are driven. Between these two drifts a system of parallel drifts on 25-ft. centers are driven (track 18-in. gage, 12-lb. rail). They are timbered with 12 by 12 in. posts 8 ft. long, dapped 1 in. deep and 1 in. back on three sides of the upper end to receive cap and collar braces and the same on one side of the bottom end to receive the sill. Caps are 12 by 12 in. by 6 ft. 10 in. overall, framed 1 in. deep and 11 in. back on three sides of both ends to fit on posts and receive collar braces. Collar braces are 10 by 12 in. by 4 ft. 2 in. overall, framed 1 in. deep and 1 in. back on one side of the two ends to fit in with cap, placing posts on 5-ft. centers. Sills are 6 by 12 in. by 6 ft. 10 in. overall, framed 1 in. deep and 11 in. back on the top side of both ends to receive posts. In sections where the ground is especially heavy a 6 by 12 in. by 2 ft. filler block is placed under center of cap, and supported by angle braces extending diagonally down on an angle of 45° to posts (Fig. 10). Angle braces are 10 by 12 in. by 3 ft. 6 in. long overall, beveled at each end, and are held in place by standards 6 by 12 in. by 5 ft. nailed to drift face of posts. Timbers 4 by 10 in. by 5 ft. long are generally used for top lagging, while 2 by 8 in. timbers, 3 ft. 10 in. long, are placed "louver" fashion between posts as side lagging (Fig. 11). Along the sides of each of the drifts at points 25 ft. apart stope chutes are built. They are supported by 6 by 12 in. by 4 ft. chute sills placed horizontally between posts at a height of 4 ft. 11 in. above the sill. One edge of the chute sill is beveled so as to give a dip of 30° to the chutes, which project out into the drift just far enough to be over the side of a car. They are built of 2 by 8 in. timber. While the tramming drifts are being driven a permanent raise, providing the block of ore is thick enough to warrant such an expenditure, is run up in much the same way as described in the "Ray Sub-Level System" to a sub-level which is near the top of the orebody. From this raise on the sub-level a drift is run along one side of the block of ore, and is usually over, and parallel with, a fringe drift on the tramming level. Out of this drift, at intervals of 75 ft., manway or ventilation drifts are driven completely through the area to be stoped. These drifts are placed so as to be over tramming drifts, so that when manway raises are run up from manway chutes, which are built along the tramming drifts near the side of a stope to be, they break into the manway drifts and become, when chain ladders are put into them, openings through which men may pass up and down from one level to the other, and later serve as means of access to stopes from the sub-level.

Stoping.—In starting a stope, raises are run out on flat inclines direct from the stope chutes until they intersect, as was the final practice at Bingham. However, at Ray all drawing-off chutes (stope chutes) for a stope are along the same straight line in the centers of the stopes instead of staggered fashion. After the raises all along a stope have been connected they are widened out to give a stope 15 ft. wide, which is mined upward in the same manner as explained for the sub-level system.

Entries to the stopes from the tramming level are provided by building up a 3 by 3 ft. cribbed manway with the opening into the stope always above and clear of the broken ore. These manways are 75 ft. apart along the side of a stope and lie directly below the manway raises leading to the ventilation or manway level. By placing the cribbed manways directly under the manway raises very little ore falls into them, so they can, at the beginning of a shift, be quickly emptied, allowing men to enter the stopes without loss of time.

Undermining Pillars.—After all the stopes in a block have been finished the work of undermining pillars preparatory for reserve drawing is very simple, as the method is the same as for starting a stope. Pillar chutes, four in all to each pillar in each drift, are built in drift sets midway between each pair of stope chutes and each is so placed as to be directly opposite another. Raises are run out from these pillar chutes, and when all in the same pillar have been connected up, widened out and blasted, the remaining ore in the block, which amounts to 80 per cent. of the total, is ready to be drawn. Winzes, termed dumping chutes, to a

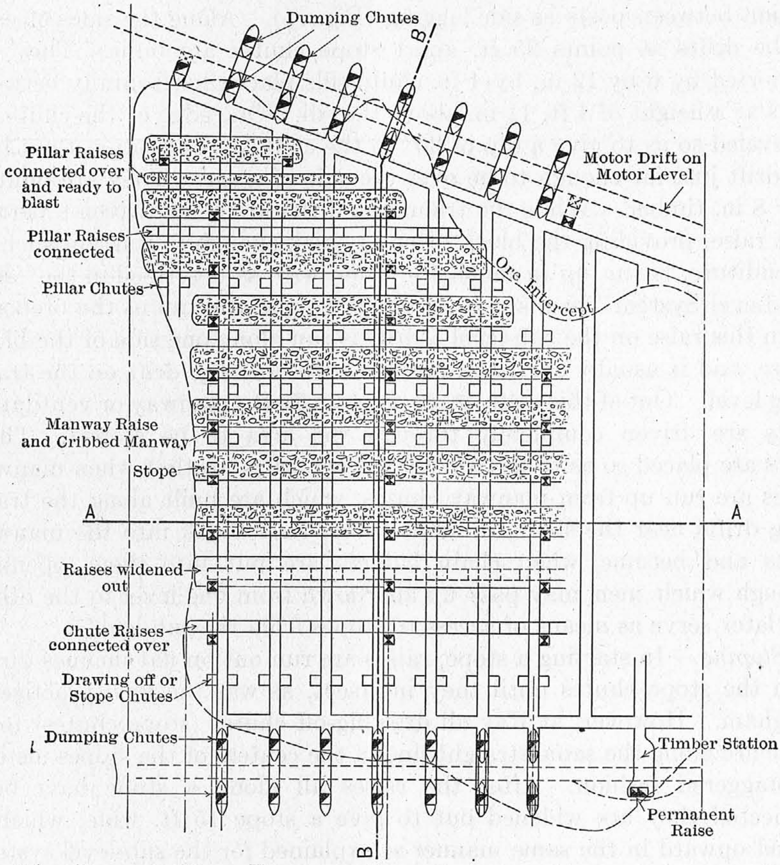


FIG. 9A.—PLAN OF HAND-TRAMMING LEVEL, SHOWING ARRANGEMENT OF STOPE MANWAYS, STOPE CHUTES, PILLAR CHUTES, AND DUMPING CHUTES.

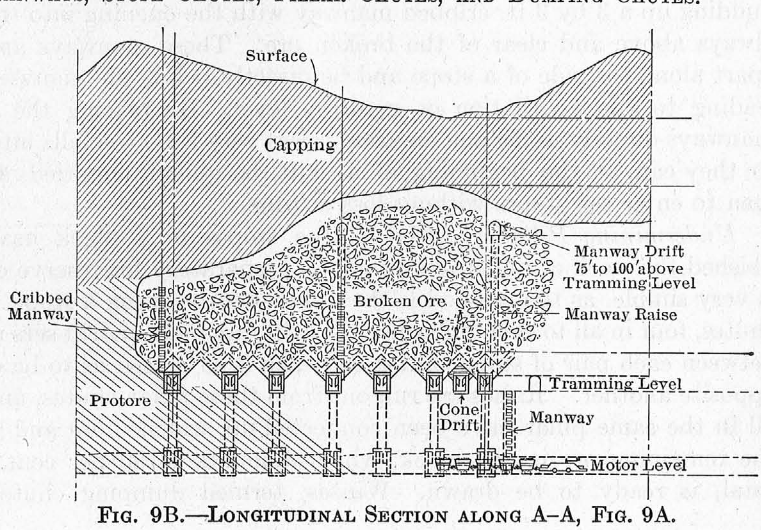


FIG. 9B.—LONGITUDINAL SECTION ALONG A–A, FIG. 9A.

motor level below are provided at the ends of each drift, and after the ore is dumped into these chutes by the trammers it is drawn out into the 5-ton motor cars and taken by electric haulage to the shaft.

Cone Drifting.—In actual practice it has been found impossible to recover all the 80 per cent., as some ore packs in the form of cones over the hogbacks between the tramming drifts; therefore, after all the chutes

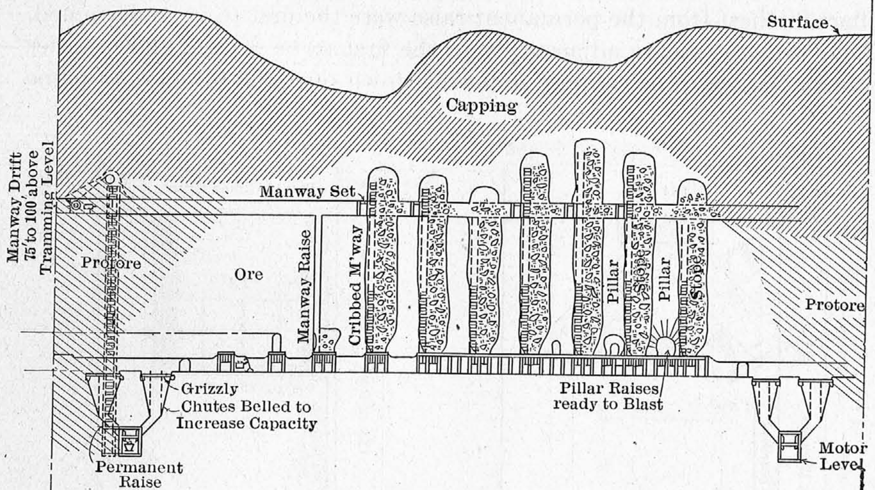


FIG. 9C.—CROSS-SECTION ALONG B–B, FIG. 9A, SHOWING SHRINKAGE STOPES AND PILLARS AND DUMPING CHUTES TO MOTOR LEVEL.

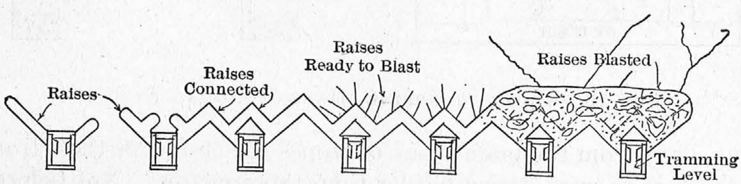


FIG. 9D.—METHOD OF UNDERMINING PILLARS.

FIGS. 9A TO 9D.—"RAY SYSTEM" OF UNDERGROUND MINING. SHRINKAGE STOPES AND PILLAR CAVING WITH HAND TRAMMING. DRAWING-OFF CHUTES IN CENTER OF STOPE AND TRAMMING DRIFTS AT RIGHT ANGLE TO STOPE.

in the original drifts have been drawn to capping, drifts termed cone drifts are driven down the centers of the 18-ft. pillars. These are timbered the same as the original drifts; chutes are built in every set and drawn, until capping appears. The additional ore remaining in the small pillars on either side of these cone drifts is recovered by gouging out along the sides of the cones.

Reserve Drawing.—In "reserve drawing" a block of ore (that is, extracting the 80 per cent. remaining after all active stoping has been completed) four factors must be kept constantly in mind: 1, recede toward solid ground; 2, draw rapidly; 3, systematize the drawing; 4, repair broken timbers immediately.

1. Receding toward Solid Ground.—It has been found impracticable to draw large blocks of ore evenly over their entire area, owing to crushing of timbers, which necessitates high expenditures for timber repairs. However, in several blocks now completely finished good results were obtained by what is termed locally the "receding method." The two pillars farthest from the permanent raise were the first to be undermined. They, with the stopes adjacent, were the first to be drawn, and in order to have the waste or capping following down over the ore on an incline

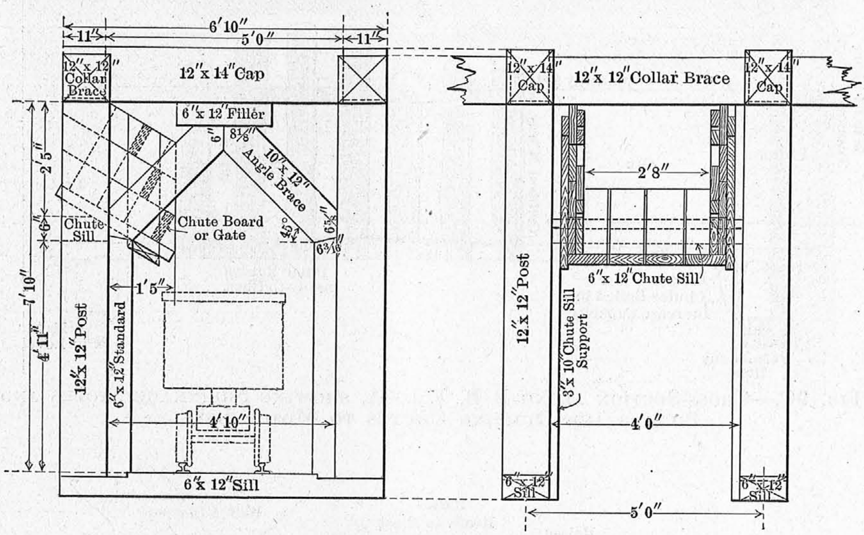


FIG. 10.—DRIFT TIMBERING, HAND-TRAMMING SYSTEM.

dipping away from the main block of stopes the chutes farthest from the permanent raise were drawn harder than those nearer. Not before, but by the time the first row of chutes had been drawn to capping, was the next pillar nearest the two already undermined, blasted, shattered, and made ready for drawing. Proceeding in such a manner no area more than 50 to 75 ft. in width was crushing and caving at any one time, and as fast as the line of chutes farthest away was drawn to capping it was abandoned, allowed to crush, and a new line provided by undermining the pillar next in order. The advantage of this process of receding was that any drift beneath the area being drawn could take weight and crush completely but still be recovered at a very small total cost.

2. Drawing Rapidly.—It is advisable to pull the ore out quickly once an area has been undermined, since by so doing in most cases all ore can be recovered without any timber repairs being necessary. The determination of the economical proportion of the non-producers, such as

timbermen, timber helpers, chute blasters, screenmen, car checkers, and bosses, in a section, to the actual producers, such as trammers and

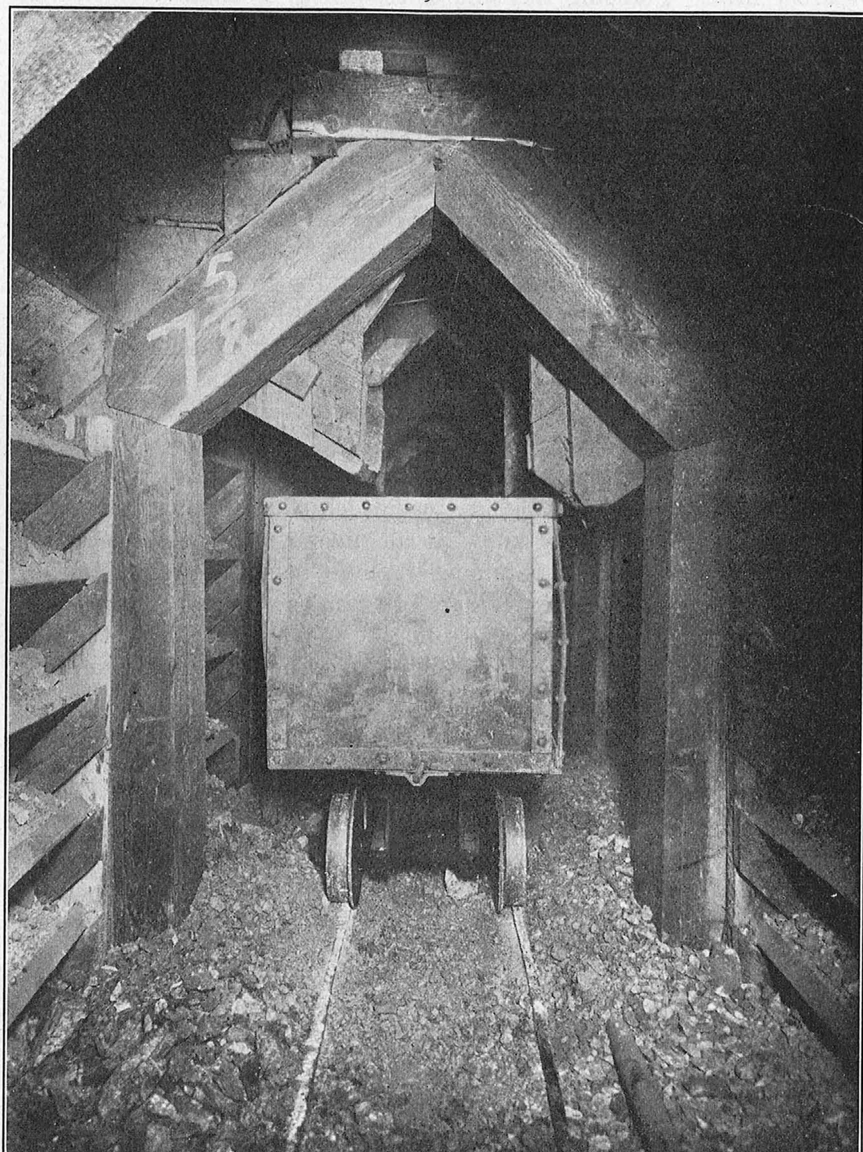


FIG. 11.—TRAMMING DRIFT IN HEAVY GROUND. SHOWING CHUTES, ANGLE BRACES, STANDARDS, AND "LOUVER" LAGGING.

muckers, is essential in order to secure the lowest final cost per ton. In other words, as many trammers as can be used without their interfering with each other should be employed in drawing any block of ground, and therefore it is usually advisable to provide a dumping chute at both ends of every drift. Pursuing this line of reasoning, it might seem advantageous also to have a dumping chute in the center of each drift, but the impracticability of such an arrangement has been demonstrated by the fact that the drifts are thereby weakened and crush, cutting off communication from end to end. Recently in a section with the dumping chutes arranged at the ends of the drifts eight trammers during a shift of 8 hr. produced 770 tons, or an average of 97 tons per trammer. Trammers are given a bonus for each car over a certain number, and are therefore at all times willing to put forth their best efforts.

3. Systematizing the Drawing.—Owing to the great number of chutes being drawn at a time a constant vigilance and record must be kept of each, so that not only the tons remaining, but the assay value, may be known at all times. With such information there is no reason why the total output in tons, assay value, and cost for producing same need fluctuate from day to day.

The duty of the car checker is to notify the boss at the beginning of each shift, or even the day before, just which chutes are ore and which are waste, so that he may know at all times which should be drawn, where to place his men for obtaining the most beneficial results and just when to undermine the next pillar. It can be seen that by such an arrangement the boss is responsible for the tons produced and the total cost for same, while the car checker must keep the assay value constant; and with such coöperation the best of results must naturally ensue.

4. Repairing Broken Timbers.—If the timbers in any drift crush it is essential to rush the repair work from both ends. A constant supervision of repairs needed must be enforced at all times in order that no ore may be left behind. In most cases drifts taking weight are detected immediately, and the work of drawing out the ore is rushed sufficiently to recover all ore before the drift becomes impassable, thus effecting a big saving for timber repairs. Most drifts crush very gradually, and none collapse suddenly.

Handling Broken Ore and Waste

On each motor level a 3-car tipple (see Fig. 12) placed directly over an ore pocket has been installed. The tipples are similar to those used in coal mining and are arranged to receive three 5-ton motor cars at a time. The 5-ton cars, in trains of 12 cars, are brought to the tipple by motors which weigh 10 tons each. When three cars have been spotted in the tipple by the motorman, the tipple operator turns on the electrical power and the tipple is rotated and the cars of ore turned completely over, allowing the ore to fall into an ore pocket. The pockets are usually 10 by 28 by 25 ft. deep, holding from 250 to 300 tons. From a pocket the ore is fed through air-dropped gates (Fig. 13) to measuring pockets, size 4 by 4 by 12 ft., holding from 10 to 12 tons—a skip load. From the measuring pocket the ore goes through an air-lift gate to a 10-ton skip, size inside 4 ft. 8 in. by 5 ft. by 10 ft. deep, in which it is hoisted (Fig. 14) vertically to the surface and dumped into an ore bin near the top of headframe. (Recently at the No. 1 hoist 364 skips (4,004 tons) of ore were hoisted during a shift of 8 hr.) Shafts 1 and 2

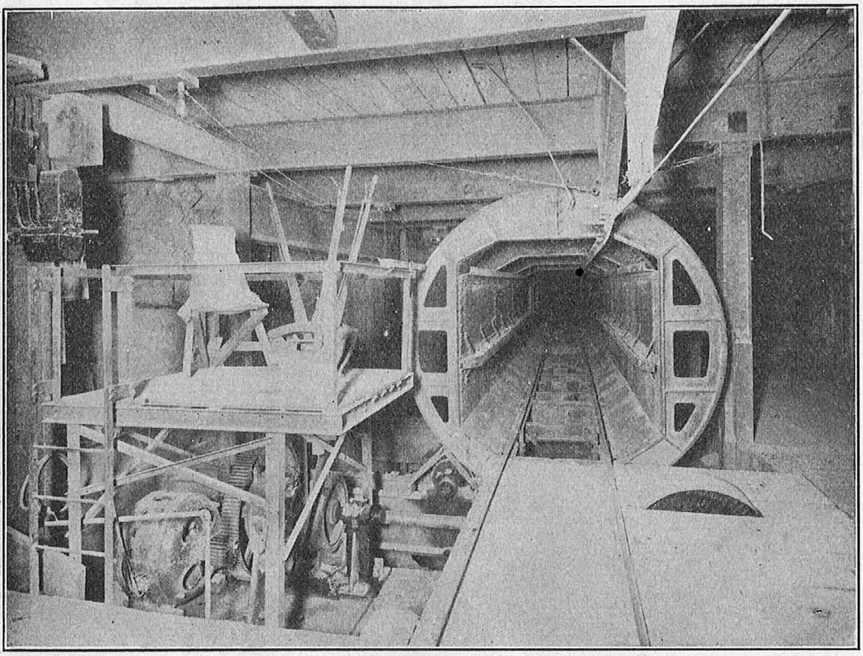


FIG. 12.—TIPPLE, WITH ORE POCKET DIRECTLY BELOW IT.

have two compartments, size 6 by 6 ft. 10 in. The ore then passes through one of four air-lift gates and over a grizzly. The oversize goes to two size 8, style K Gates gyratory crushers, and unites with the undersize from the grizzly, then into a bucket elevator which hoists the ore to the top of building and allows it to pass over an inclined screen chute to two Garfield rolls, size 72 by 20 in. The undersize from the screened chute unites with the crushed ore from the rolls and is fed on to an inclined conveyor belt which takes the ore to the top of a storage bin. (At No. 2 shaft the storage bin holds 5,000 tons while the one at the No. 1 shaft holds 25,000 tons.) From these bins the ore is drawn off through basket gates into railroad cars of 60-ton capacity and shipped to the

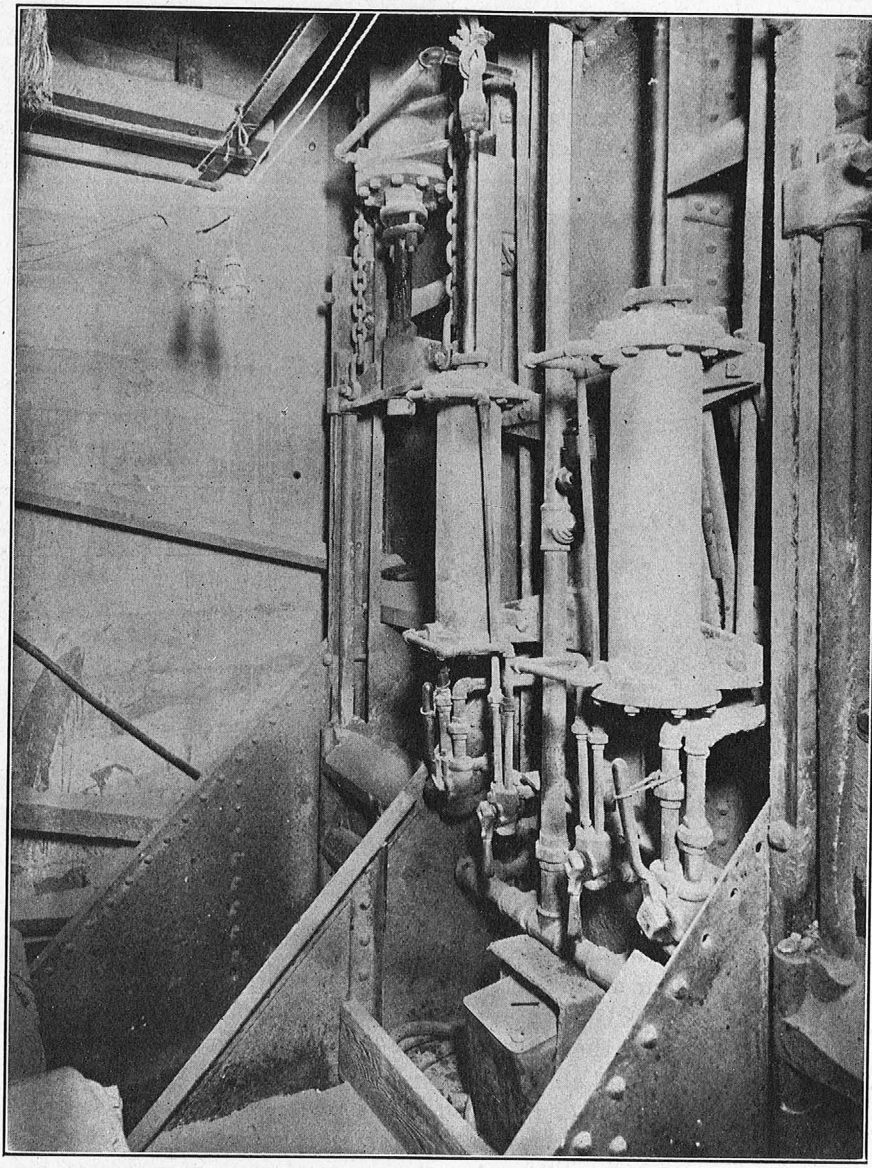


FIG. 13.—AIR-DROPPED GATES, BETWEEN ORE POCKET AND MEASURING POCKET.

concentrator at Hayden, 23 miles from Ray. The ore is usually sent to Hayden in trains of 38 cars, or about 2,400 tons to a trip.

The waste encountered during development and prospecting work is loaded into V-shaped side-dump cars of 45 cu. ft. (2¼ tons) capacity. These cars are hauled by the motors to a winze, and dumped, the waste falling to a pocket directly over an inclined shaft. From the pocket the waste is fed through hand-operated arc gates to skips, size 60 cu. ft. (hoisting capacity 2½ tons). The skips are hoisted to the

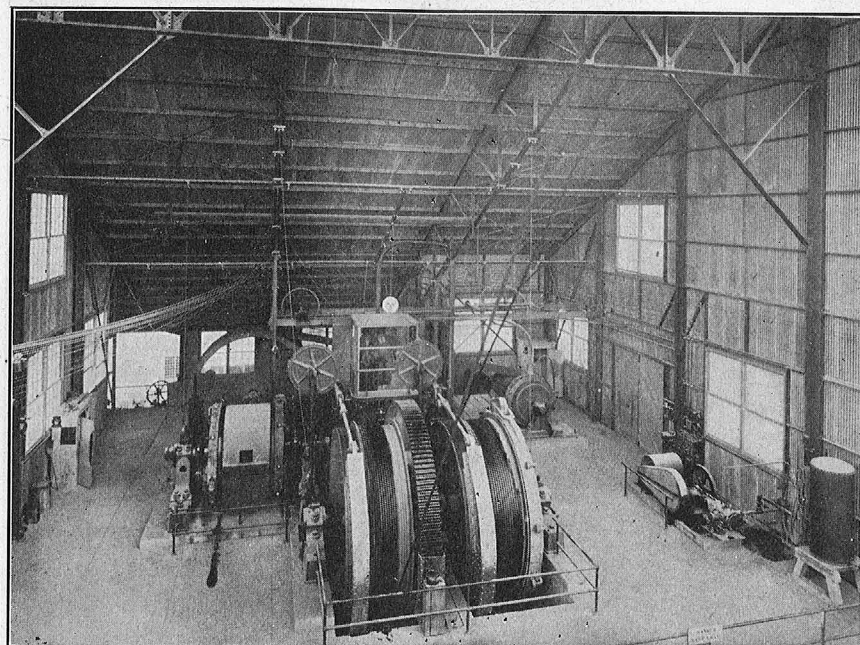


FIG. 14.—THE ELECTRIC HOIST.

top of a 30° incline shaft, where the waste is dumped into a cylindrical iron bin of 10,000 cu. ft. (500 tons) capacity. The No. 1 incline shaft (material hoist) has three compartments, each 5 by 7 ft. Two compartments are used for supplies and waste, while the third contains air pipes, water pipes, electric wires, and a stairway for the men. No men are hoisted or lowered, so that all those working on the lower levels use the stairways (Fig. 15).

The waste is drawn out of the bin into small crab cars and distributed for ballast on railroad, or filling (gobbing) square sets at No. 3 mine.

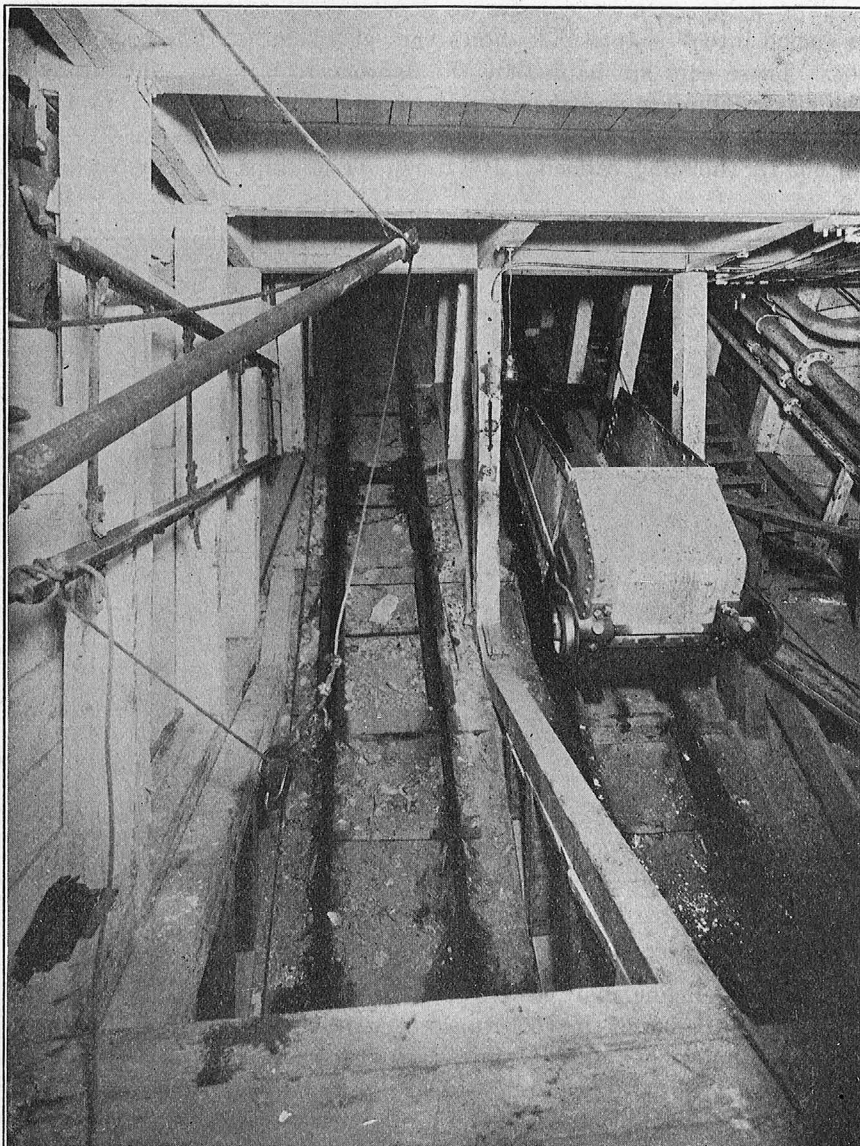


FIG. 15.—INCLINE OR MATERIAL SHAFT. SHOWING SKIP, TWO HOISTING COMPARTMENTS, AND STAIRWAY; ALSO AIR AND WATER PIPES, AND ELECTRIC WIRES.

Engineering Work in Connection with the "Ray System"

In efficiently handling the "Ray systems," engineering is of necessity the paramount fundamental. From the time churn drilling is started to the final drawing of a stoped area, the engineering department, in co-operation with the management, must be wary and alert.

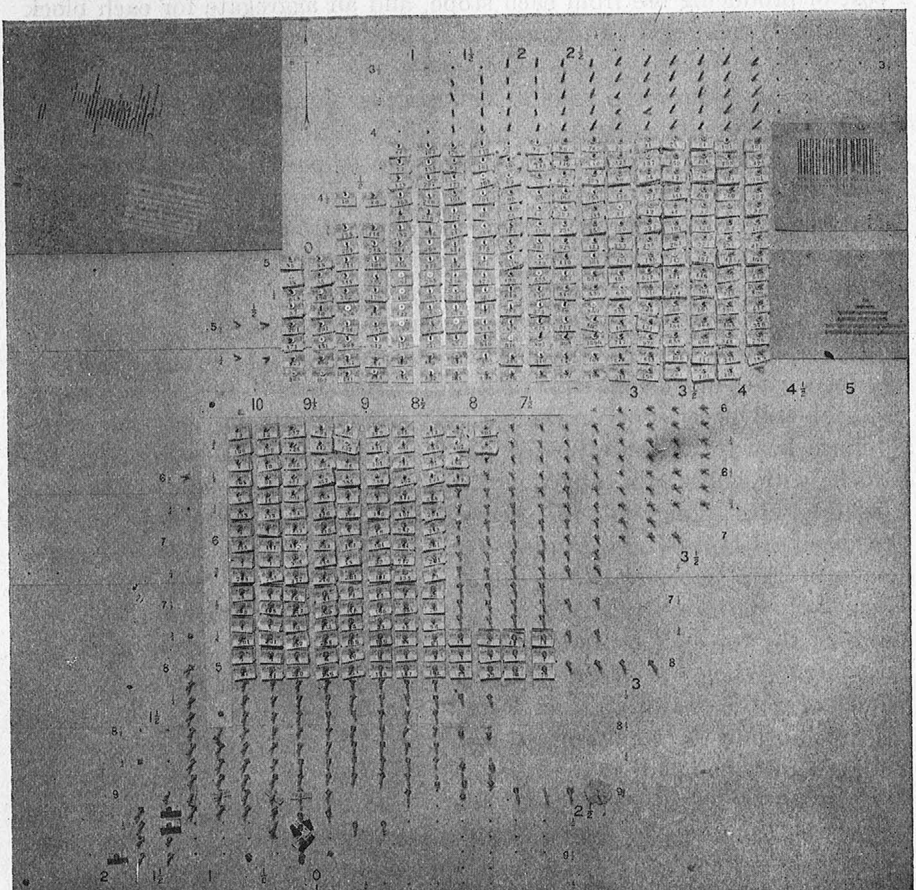


Fig. 16.—Chute Board. Showing the Pads with Numbers for Determining the Ore Remaining in Chutes.

Records, maps, and drawings are kept by engineers of each successive step leading up to and during active stoping and reserve drawing of every block of stopes.

A transitman with his helpers is responsible for correct reports on grades, bearings, timbering and proper connecting up of all drifts, inclines, raises, shafts, etc., and plotting of same on maps and sections.

The sampling department takes groove samples at intervals of 5 ft. in all headings, and records assays on maps, sections, and in permanent office record.

"Stope engineering" covers the work of efficiency in underground mining and in making reports and suggestions from time to time for betterment in operation; keeping records of the tonnage obtained and cost of producing ore from each stope, and an aggregate for each block of stopes; making semi-monthly cost and tonnage reports, which are posted on a bulletin board at "Candle House," where all the bosses may see and know the results that each is obtaining in his particular section of the mine; taking samples from time to time along the back of each stope while active so as to keep bosses posted as to whether the stope back is in ore or waste (these assays are entered upon the stope sections); also calculating tonnage and assay value of each block of ore with a proportional distribution of same to each chute to be drawn, therefore by keeping account of all ore drawn from each chute, the amount still remaining is known, and an even settlement of the ore and capping can be effected; keeping the management informed not only as to the surface movement over each area, but also as to the ore remaining in each and every chute in the various sections of the mines by means of "chute boards." These boards are 6 ft. wide, 7½ ft. high and 1 in. thick, with holes 2 in. apart horizontally and 1¼ in. apart vertically (see Fig. 16). Each hole represents a chute, and is drilled large enough to receive a bolt 3/16 in. in diameter. Bolts are 3½ in. long to receive pads of thin paper or tickets which are printed with consecutive numbers. Each ticket is 1 by 1¾ in. in size and perforated through the center; the top half contains a hole for the bolt, and the lower half, a number. When ore is drawn from any chute, tickets indicating the amount of ore drawn are torn from the pad representing that chute. A ticket showing the total amount of ore in each chute is placed over the upper half of the pad, so that it is easy to determine the tons of ore still remaining by deducting the number on the lower half from the one on the upper half of the pad representing that particular chute. Figures are placed across the top of a board to designate the drifts, while others down the side indicate the chutes.

Permanent Stope Records are kept by the stope engineers showing the tons produced, together with cost and assay value of same, for each stope, both during active stoping and reserve drawing; also for pillar drifting, cone drifting, and cone stoping. The information for these records is obtained as follows:

A stope card for each class of work (Fig. 17) is turned in to the engineering office by the boss after every shift. Each card shows the labor and material used during that shift chargeable to stoping operations. The items chargeable to stoping operations in the sub-level system are:

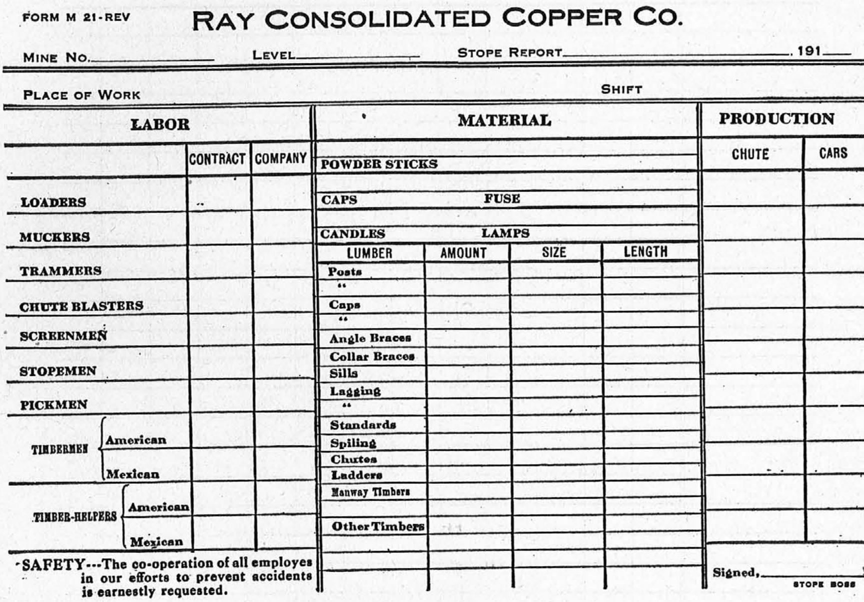
1. All work of every description above the first sub-level within the block of ground to be stoped, preparatory for stoping, except that pertaining to manway drifts and stope drifts.

2. Belling and widening out of chute raises.

3. After all active stoping has been completed and reserve drawing begun all work of every description within the stoped area on and above the motor-haulage level.

4. All work pertaining to pillar drifting, cone drifting, and cone stoping.

5. All work of recovering timber after reserve drawing has been finished and section abandoned.



FORM M 21-REV RAY CONSOLIDATED COPPER CO.

MINE NO.______ LEVEL______ STOPE REPORT______ 191__

PLACE OF WORK SHIFT

LABOR			MATERIAL				PRODUCTION	
	CONTRACT	COMPANY	POWDER STICKS				CHUTE	CARS
LOADERS			CAPS	FUSE				
MUCKERS			CANDLES	LAMPS				
			LUMBER	AMOUNT	SIZE	LENGTH		
TRAMMERS			Posts					
			"					
CHUTE BLASTERS			Caps					
			"					
SCREENMEN			Angle Braces					
			Collar Braces					
STOPEMEN			Sills					
			Lagging					
PICKMEN			"					
			Standards					
TIMBERMEN American			Spiling					
			Chutes					
TIMBERMEN Mexican			Ladders					
			Manway Timbers					
TIMBER-HELPERS American								
			Other Timbers					
TIMBER-HELPERS Mexican								

SAFETY---The co-operation of all employes in our efforts to prevent accidents is earnestly requested.

Signed,______ STOPE BOSS

FIG. 17.—STOPE REPORT BLANK.

In the hand-tramming system the charges to stoping operations are:

1. All work of every description above the tramming drifts within the area to be stoped, except manway drifts.

2. After active stoping has been finished and reserve drawing started, all work on the tramming level and sub-level within the area stoped.

3. Cone drifting with the necessary timbering; chute building and cone stoping in same.

4. Recovering all good timber after cones have been drawn and section abandoned.

A car report (Fig. 18) is obtained from the car checkers showing the number of cars drawn from each chute, with a grand total for the section.

Samples are taken of the ore from each chute, by the trammers or car pushers throwing into a box a handful from each car drawn. These samples, after being properly tagged by the car checker, are turned over

Form M-34

CLASS

PAGE

CAR REPORT

RAY CONSOLIDATED COPPER CO.

MINE No.______ LEVEL No.______

______SECTION

DATE______191__ SHIFT______

STOPE													
TOTALS													

TIPPLE ______CARS

FOUND LOADED______CARS

LOADERS ______

CHUTE BLASTERS______

GRAND TOTAL______CARS

SIGNED______

FIG. 18.—CAR REPORT BLANK.

to the trammers, who are responsible for their proper delivery to the assay office. At noon of the following day an assay sheet is posted in the engineering office where the car checkers may see the value of the samples taken the previous day and regulate drawing accordingly.

Stope Record Sheets

In the monthly record a separate account is kept for each stope. Each account consists of two pages. One page is used for labor and material, forming the cost sheet (Fig. 19). The other sheet is used for a car record and forms the tonnage sheet. All cost sheets are kept together, likewise the tonnage sheets. Each sheet is ruled to accommodate one month's run. Several other extra sheets are also kept as a summary check on the entries of the others.

All entries on the cost sheets are made in terms of shifts or fractions of a shift under the various labor headings. Material is debited under the proper heading according to the units reported for each class. A price list and wage scale are kept near at hand. At the end of each 15-day period the total is found for each item and multiplied by the price. Cross additions are then made to get total labor and total material. The sums of these give the total labor and material.

The car reports from the various stopes are then entered on the proper tonnage sheet in terms of cars. The total in the right-hand column gives the total cars per shift. To the right of this column the corresponding assay is entered and this multiplied by the total cars per shift gives the cars per cent. per shift, which is entered to the left of the total car column. At the end of each period the vertical columns for each chute are added and their sums must check with the sum of total cars per shift column. Each of these totals is then multiplied by a factor to reduce each from cars to tons. The cars-per cent. column is then footed up and multiplied by the same factor to get tons-per cent. Tons-per cent. is then divided by the total tons to get the proper assay average for the period. Similarly, the total cost of labor and material is divided by total tons on each sheet to get the cost per ton.

As a check on the price multiplication the shift sums from the bottom of each column are entered by stopes on a separate sheet and these correspondingly totaled up. Each sum is then multiplied by its proper rate and the total of this should check the total of the labor and material columns of all the stope sheets. Any error is thus quickly traced.

As a check on the car entries a separate sheet is kept for the total cars per shift as given on each car report. The sum of these totals should check with the sum of the total cars per shift column of all the stope tonnage sheets. The tons-per cent. entries have no independent check, but all assays are carefully entered and all multiplications for cars-per cent. checked by casting out the nines. Average assays and costs per ton are obtained by the slide rule with sufficient accuracy, but are checked

RAY CONSOLIDATED COPPER CO.

TOPE COST RECORD

RAY, ARIZONA

MINE NO.......... STOPE..........

LEVEL.......... ....191....

Shift	Loaders	Trammers	Chute Blasters	Screen Men	Stope Boss	Stopemen	Pickmen	Timbermen	Timber Helpers		Car Checkers	Assaying	Others	Total Labor		Powder	Caps	Fuse	Candles	Machine Drill Exp.	Timber		Total Material		Total Labor & Material	Production, Tons	Cost per Ton		Total Labor & Material	Production, Tons	Cost per Ton	Date
Day																																1
Night																																
Day																																to
Night																																
Day																																15
Night																																
otal for Period																																
mount																																
Day																																16
Night																																
Day																																to
Night																																
Day																																31
Night																																
otal for Period																																
mount																																
otal for Month																																
mount																																

Fig. 19.—Stope Record Sheet.

by repeating. So far the checking has only been for the benefit of the office work. As a check on the stope cards themselves, or any missing cards, the various costs for the period are grouped under the headings of: 1. Breaking; 2, tramming; 3, timbering; 4, engineering, etc.

The first includes stope bosses, stopemen, and pickmen.

The second includes loaders, trammers and muckers, chute blasters, and screenmen.

The third includes timbermen and timber-helpers.

The fourth includes car checkers, assaying, engineers, etc.

The sum of these items should equal the total labor as found from all the cost sheets. To this figure is added total material. The final sum must check with the total labor and material from all cost sheets. The totals thus segregated are then comparable with the cost accounts as kept by the clerical force, these being independently made up from the mine timekeepers' reports.

To reduce and concentrate the bulk of these monthly records, a separate cover is used for the summary sheets. The form for these sheets is identical with those used for daily entry. The totals for each column in terms of cost only are entered at the end of each period with the date. A separate sheet is kept for each stope. The upper half of each sheet is used for costs and the lower half for tonnage. On this latter the entries are made in terms of tons and tons-per cent. only. On the extreme right of each sheet are carried the totals to date of labor and material, production in tons, and tons-per cent. The average costs per ton and assay to date are also calculated and entered.

Comparative Advantages of the Two Systems now in Use at Ray

It must be remembered that the sub-level system is only applicable in sections of a mine in which the orebody covers a considerable area and has a height exceeding 100 ft. The development of the stope laterals is necessarily expensive; the timbering is costly; and considerable expense is incurred in equipping and maintaining the drifts for motor haulage. Unless the orebody is of sufficient area and height to repay the cost of the initial large expenditure, the sub-level system should be abandoned in favor of the hand-tramming system. The great advantage of the motor-haulage system is that it is capable of producing a comparatively large tonnage, not only in the operation of putting up the active stopes in the section, but more especially when reserve-drawing operations are started. The tonnage per shift that can be produced from a reserve in a sub-level section is practically only limited by the efficiency of the electric-haulage system and the capacity of the shaft and pocket equipment. If such conditions are at hand, the sub-level system will produce a large output at a very low cost. However, in sections of the mine where

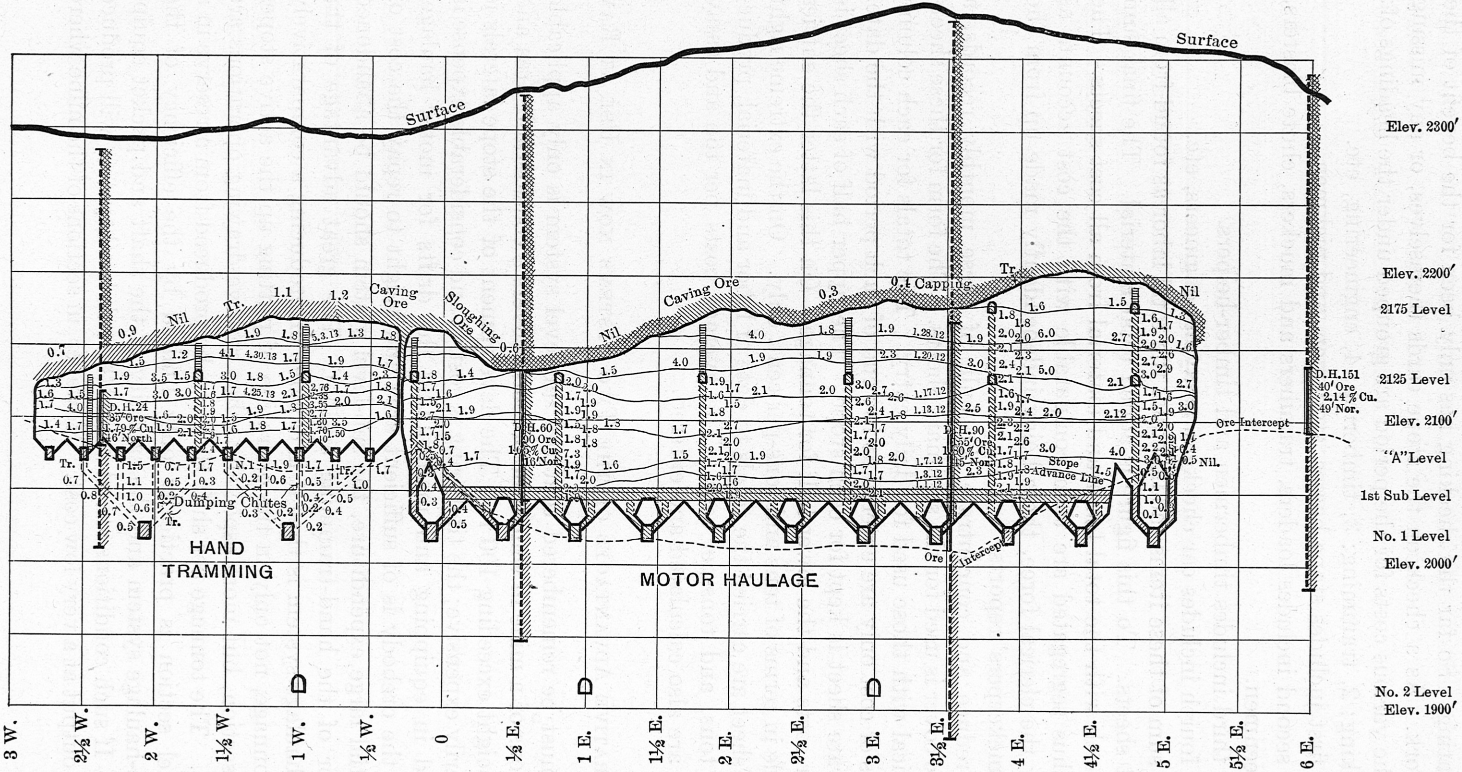


FIG. 20.—SECTION SHOWING PORTIONS OF THE OREBODY ADAPTABLE TO THE MOTOR-HAULAGE SYSTEM AND THE PORTIONS ADAPTABLE TO THE HAND TRAMMING SYSTEM.
A SIMILAR SECTION IS KEPT FOR EACH STOPE, SHOWING ORE INTERCEPT, MANWAY-RAISE ASSAYS, STOPE ASSAYS, AND STOPE ADVANCE LINE.

the ore is of less extent and of a height less than 100 ft., the hand-tramming system, primarily owing to the small initial expenditure, will be found more economical to install (Fig. 20). Its advantages over the sub-level system may be enumerated as follows:

1. Less development work is required, with a consequent lower total expenditure; only a small capital outlay is necessary before stoping can be started, and a big tonnage supplied; no great amount of money is tied up for initial expenditures, whereas with the sub-level system all the big expensive motor-haulage drifts must be completed before any ore is obtained from stoping; also the outlay for track, pipe, and trolley wire is high.

2. The total outlay for timber is less, hence the system is adaptable to localities where timber is expensive and difficult to obtain.

3. The total cost for maintaining drifts is lower. When one of the small tramming drifts caves it can be repaired readily with a small outlay, whereas if any of the motor drifts in the sub-level system crush, the repair work is not only expensive, but the time required may result in cutting down the daily output.

4. A higher final extraction can be obtained, as chutes can be built in every set in both the original and cone drifts, thus supplying drawing-off chutes at frequent intervals at the base of the block of ore; but with a sub-level only 30 ft. above the haulage level it is not advisable to cut up the pillar below the sub-level with drawing-off chutes too close together, owing to the danger to the important haulage drifts below; also, the work of running up the raises to the sub-level increases the total cost per ton of ore obtained from a block.

5. The hand-tramming system is adaptable to shallow as well as deep orebodies because of the small outlay for initial development work.

6. The rapidity with which a block can be opened up and made ready for producing ore is an additional advantage of hand tramming.

Conclusion

The "Ray systems," although as yet comparatively new in their application, have amply justified all expectations.

The systems have been used in both hard and soft ground. In blocks where the ground is very hard the stopes are carried wider than the regulation 15 ft., thus leaving the remaining pillars narrower and more readily shattered by undercutting. This feature of narrowing and widening stopes according to the nature of the ground insures at all times the safety of the miners, and accounts for the fact that very few accidents occur actually within the stopes. The stopes are under constant supervision, with the backs closely watched and inspected before each drilling.

The method of mining is adapted to the use of stoper (air-hammer) machines, so that only a few men are needed in producing a big tonnage. All stopes are mined in much the same way and systematically, consequently the men soon become proficient in their work. Since all blasting is done at the end of each shift, but little time is lost. Practically no timber is used above the motor or tramming levels, and in comparison with other caving systems little raising and drifting is done. With the sub-level system even the "stope drifts" on the first sub-level may be done away with by simply connecting over raises direct from chutes on the motor level, as outlined for "Undermining Pillars."

In conclusion, it is but necessary to emphasize the great flexibility of the systems. Practically any number of men can be used during active operations and a corresponding tonnage produced, and when circumstances require it the number of men and tonnage can be either increased or decreased without materially affecting the total direct mining cost per ton.

Discussion

Sidney J. Jennings, New York, N. Y.—In the historical part of the development of the caving system discussed by Mr. Blackner, I notice the absence of one man's name, Charles Henroten. Mr. Henroten used the caving system in South Africa in the Kimberly mines, and realized from his work there that ground would cave when properly prepared. I think it is due him that his name should be mentioned in connection with an exposition of this system in America.