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AUTHOR Vanderburg, William O
TITLE Mining methods and costs at the Argonaut mine, Amador County, California
IMPRINT [Washington, D.C.?] : U.S. Dept. of Commerce, Bureau of Mines, 1930.
UNI TITLE Technical Report Archive & Image
ISBN
FORMAT Book
EDITION

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MINING METHODS AND COSTS AT THE ARGONAUT MINE, AMADOR COUNTY, CALIFORNIA

BY

WILLIAM O. VANDERBURG

I.C.6311
August, 1930.

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MINING METHODS AND COSTS AT THE ARGONAUT MINE, AMADOR COUNTY, CALIFORNIA[1]

By William O. Vanderburg[2]

INTRODUCTION

This paper describing the mining practices at the Argonaut mine, Amador County, California, is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States.

The mining practices described are those used in exploiting the low-grade gold ores in the heavy and swelling ground that occurs on the Mother Lode belt.

The author acknowledges the assistance of E. A. Stent, vice-president, James L. Fontenrose, cost clerk, Joseph Mohorovich, mine foreman, of the Argonaut mine, and of E. D. Gardner, supervising engineer, United States Bureau of Mines, Southwest Experiment Station, Tucson, Ariz.

Special thanks are due Mr. Stent, whose courtesy and kindness made this paper possible.

The Argonaut mine is situated 1 mile north of Jackson, the county seat of Amador County, on the Mother Lode belt, which traverses a region about 1 mile wide and 120 miles long in the western foothills of the Sierra Nevada Mountains. The most productive part of the belt is in Amador County, extending from Plymouth to Jackson. The district is well situated, and a number of factors contribute to low mining costs: (1) Excellent climatic conditions; (2) nearness to supply centers; (3) abundance of water; (4) low elevation (the Argonaut mine shaft collar has an elevation of 1,250 feet above sea level); (5) cheap hydroelectric power; (6) excellent transportation facilities; (7) plentiful labor supply, except for an occasional shortage; (8) relatively small temperature increase in the mine as depth is attained.

These advantages are partly offset by: (1) Increasing cost of operation incident to the great depth to which mining has progressed; (2) the heavy and swelling ground encountered and the consequent large outlay for maintenance to keep the ground open; (3) the comparatively low grade of the ore

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6311."

2 - Associate mining engineer, U. S. Bureau of Mines.

The Argonaut mine produces about 260 tons of ore per day and employs a force of about 200 men. Most of the ore is free milling; it contains an average of 2 per cent sulphides, mostly pyrite. The yearly average grade of the ore varies from $6 to $17 per ton. The ore is treated in the company's mill which is equipped with 60 stamps and 36 Frue vanners. About 65 per cent of the gold is amalgamated in the batteries and on plates. The sulphides are concentrated on the Frue vanners and the concentrates are cyanides locally under contract.

HISTORY

Quartz mining on the Mother Lode belt began in the fifties, shortly after the first excitement of placer mining in the forty-nine gold rush had subsided. The first quartz miners were mostly Mexicans who used the arrastra method to separate gold from the ore. The early efforts at quartz mining were not very successful due to lack of capital, crude machinery, inadequate methods of recovering the gold, inexperience in handling heavy ground, and the insecure tenure by which the mines were held.[3]

Since the early days the history of most of the mines of the Mother Lode belt shows periods of activity alternating with long periods of idleness. The World War dealt a severe blow to the industry due to the decrease in the purchasing power of gold. Many mines were closed down, and at present only three large mines are operating in Amador County, the Kennedy, the Central Eureka, and the Argonaut.

The Argonaut property was opened in 1850, and was worked in a desultory manner until 1893 under the name of the Pioneer mine. The Argonaut Mining Co. was organized in 1893 and an incline shaft was started on the property after good ore was discovered in the deeper levels of the adjoining Kennedy mine. Since that time operations at the Argonaut mine have been continuous except for a period of three years when mining was discontinued due to the results of mine fires.

PRODUCTION

The total output of gold from the Mother Lode belt is estimated by the California State Mining Bureau to be about $240,000,000. About half of this amount was produced from the section of the belt lying between Jackson and Plymouth. From 1893 to 1930 the Argonaut mine has produced $16,377,252 (792,250 fine ounces).

GEOLOGY

The most recent geological description of the Mother Lode belt and its mines was written by Adolph Knopf.[4]

3 - The quartz mines were held under district rules formulated by the inhabitants, the majority of whom were placer miners.

4 - Knopf, Adolph, The Mother Lode System of California, U. S. Geol. Survey. Prof. Paper 157 1929 88 pp. Prepared in cooperation with the California State Mining Bureau.

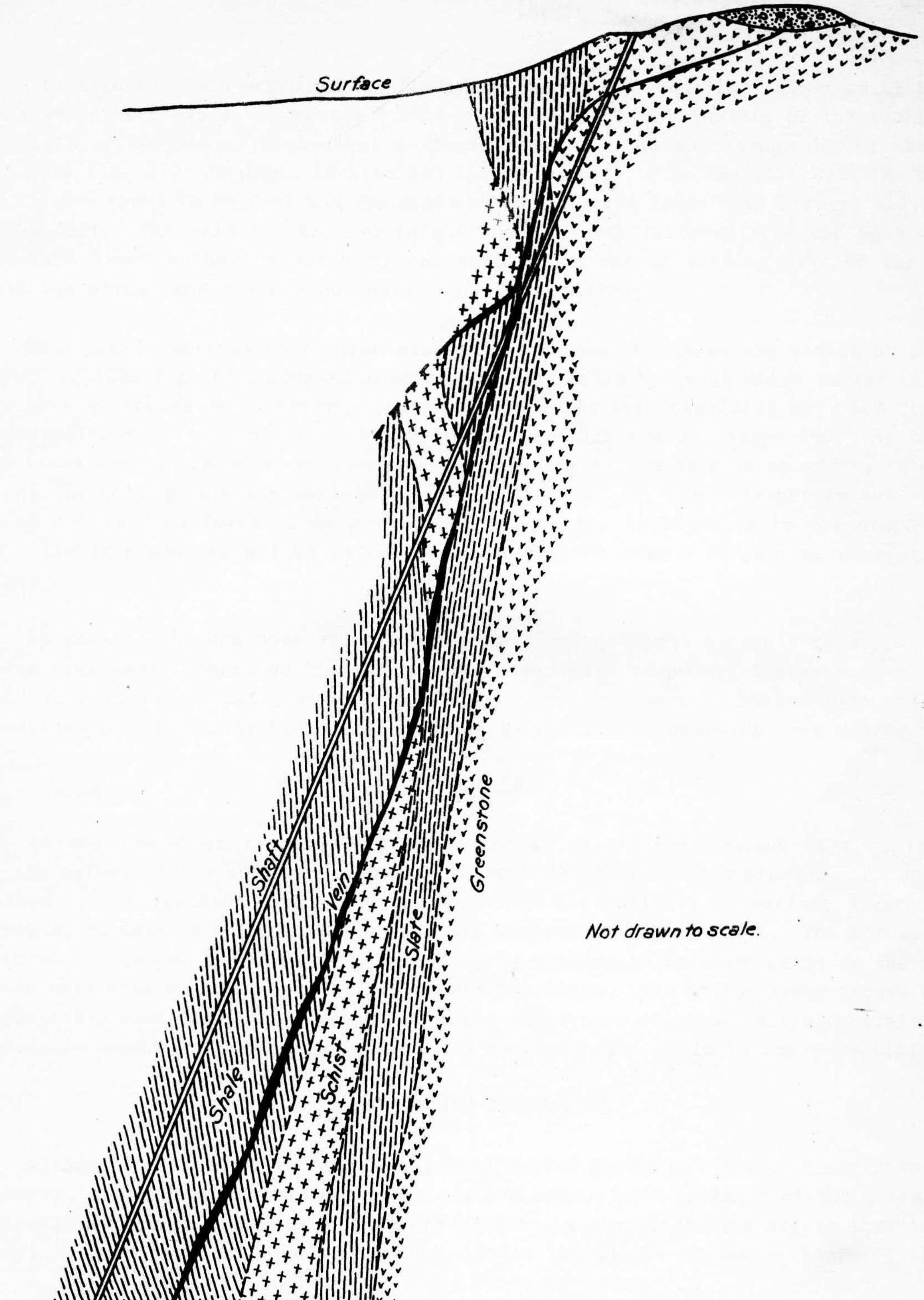


Figure I.- Vertical sketch of Argonaut vein in relation to shaft.

The Argonaut vein occupies the fissure of a reverse fault and cuts through beds of greenstone schist and slate, independent of either the strike or the dip of the rocks which form the walls. The vein strikes about north 20° west and has an average dip of about 63° northeast (see fig. 1). As depth is attained the vein tends to become flatter. The maximum width of the ore shoot is 65 feet and the maximum length 1,100 feet. The average width mined is about 20 feet. The vein is very persistent and has been followed from the apex down to the 5,400-foot level without a break of any kind. The quartz filling pinches and swells along both the strike and the dip but never dies out entirely.

Geological features other than size and dip which influence the choice of a mining method are: (1) The vein is accompanied on one or both walls by gouge which varies in thickness from several inches up to several feet; (2) the walls are invariably soft and fractured so that sloughing will take place promptly if the openings are not supported; (3) the vein itself is traversed by planes of weakness so that lagging of the back is necessary to prevent caving; (4) the rock masses are more or less mobile—that is, their weight is not uiformly distributed but is transferred from point to point as the equilibrium is disturbed by new openings. Timber alone can not be relied upon for support over a large area without danger of collapse.

In general the ore body and its walls have insufficient strength to support themselves even over small spans, so that as stoping progresses temporary timber support is required and is followed promptly by waste filling. This is the only method that has so far been found adequate for controlling the enormous weight of the shifting rock masses.

EXPLORATION

As the ore shoot is very persistent and as no radical changes have so far been found in the nature of the ore body, exploration work is not a serious problem. Prior to the organization of the Argonaut Mining Co., exploration was confined to surface trenching and the driving of an adit to cut the vein at a depth of several hundred feet. The Argonaut Company explored the deeper portions of the ore body by sinking an inclined shaft in the hanging wall of the vein with crosscuts and drifts driven therefrom. Due to the heavy ground encountered exploratory work can not be carried very far in advance of actual mining operations, as the maintenance expense entailed in keeping the workings open would become prohibitive.

SAMPLING AND ESTIMATING

Although the gold is not uniformly distributed in the ore shoot, close sampling is not necessary. One who is familiar with the ore can make a good estimate of the grade of the ore by visual inspection. When sulphides are present in the quartz the ore is invariably of good grade; the amount of sulphides, however, is not indicative of the richness of the ore.

Stope samples are taken by the trammers when the ore is drawn from the chutes. These samples, which consist of a handful of material from each car loaded, are thrown into a powder box near each chute and are combined into one general chute sample which at the end of each shift is brought to the surface for fire assay.

Development samples are taken in the same manner.

The areas stoped are platted monthly on a longitudinal section and a record is also kept of the tonnage and grade of the ore taken from each stope. From these records factors can be derived for estimating the grade and tonnage of any block which has been exposed on two or more sides. The ore body is fairly regular in its characteristics, and the factors, being derived from actual mining results, take account of dilution effects by waste rock. Consequently the grade factor and the tonnage factor (about 12.5 cubic feet per ton for solid ore and 18 cubic feet per ton for broken ore) both check closely in practice.

DEVELOPMENT

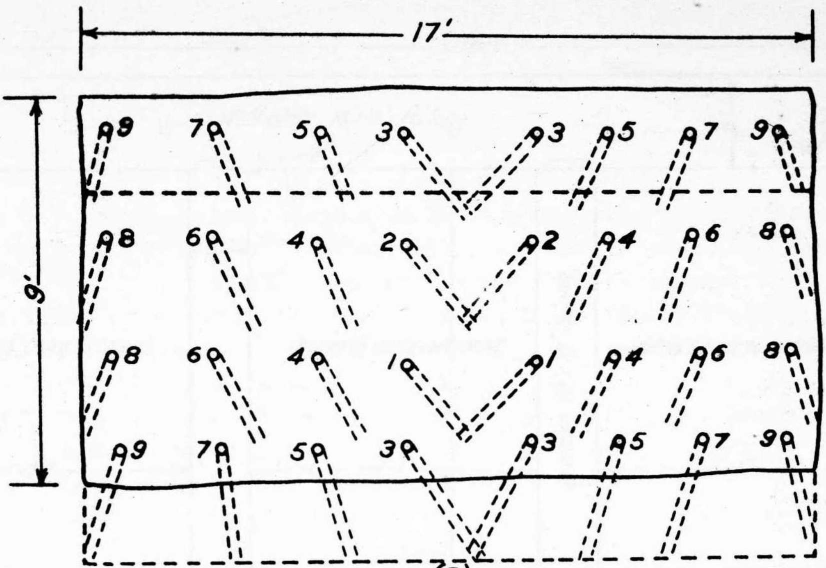
Shaft

Entry to the mine is made by a 70°-inclined three-compartment shaft 5,800 feet long sunk in the country rock in the hanging wall of the vein (see fig. 1). The level interval is 100 feet for the first 3,000 feet from the surface and is 150 feet from there to the bottom, measured on the incline. An auxiliary shaft is also maintained for ventilation purposes and for the escape of workmen in case of necessity.

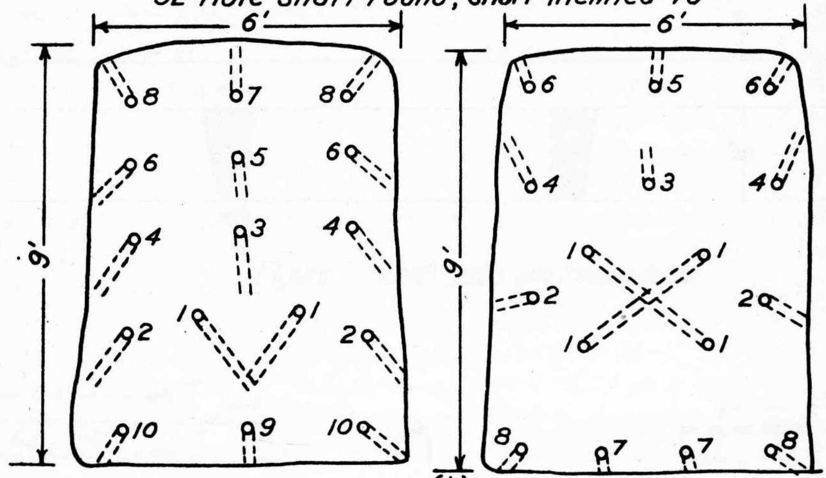
The main shaft is divided into one manway and two hoisting compartments; each compartment is 5 feet 9 inches by 4 feet 1 inch in the clear. The greater portion of the shaft is timbered with 20 by 20 inch Oregon fir sets, but the present practice is to use 16 by 16 inch wall plates 16 feet long, 14 by 16 inch end plates 6 feet long, 10 by 16 inch dividers 6 feet long, and 8 by 12 inch posts 3 feet 9 inches long. The sets are placed on 5-foot centers. Lagging consists of 2 by 6 or 3 by 6 inch planks. Shaft sets are framed as shown in Figure 3. In this method of framing the strength of the timber is not weakened to any great extent, and the framing is simple compared to some of the more elaborate methods in use. The dovetails at the corners of the set which hold the set together while being blocked could be eliminated and the ends of the wall and end plates so framed that the outside edges of the end plates are flush with the ends of the wall plates. This would further simplify the framing but the advantage gained would be lost in the extra time taken in blocking and wedging the sets in position. To prevent the bevel portion of dovetail from splitting, several spikes are driven into this part of the wall plates. In framing repair sets the dovetail is framed only on one end of each wall plate. Posts are used only at the four corners. Hanging bolts are used to draw the members of the set tightly into position.

Shaft timbers are framed on the surface by hand. Due to variation in the sizes of the timbers all dimensions for cutting the mortises and tenons are marked on only one side of each timber. Uniformity in framing is obtained by the use of wooden templates.

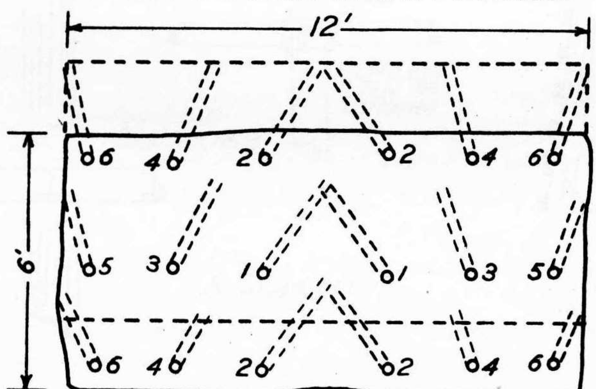
Shaft sinking is done on contract with a guaranteed minimum wage. A crew of 12 men, or four men on each of the three shifts, is required. The routine of operations in sinking a shaft is about as follows:



(a)
32-Hole shaft round, shaft inclined 70°



(b)
16-Hole crosscut or drift rounds.



(c)
18-Hole inclined raise round.

Note: Numbers adjacent holes indicate order of firing

Figure 2.

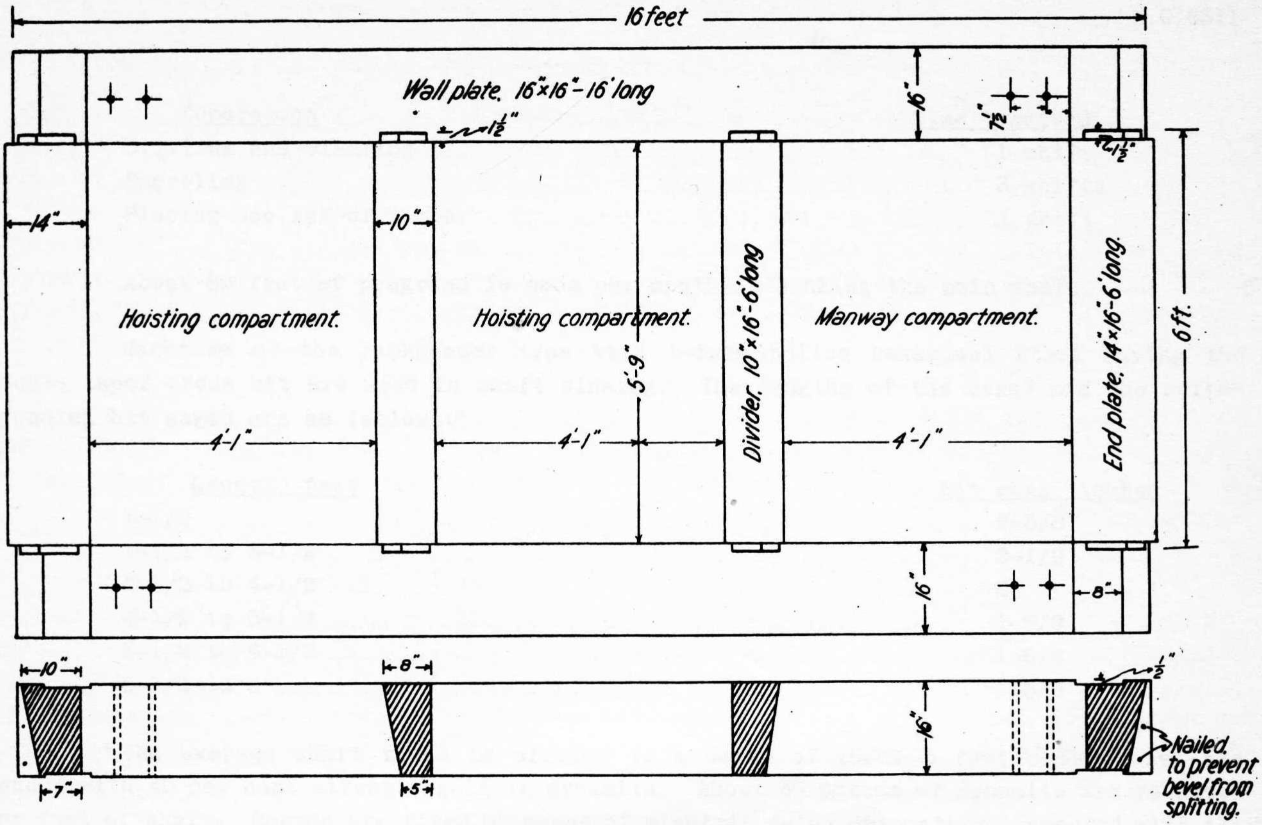
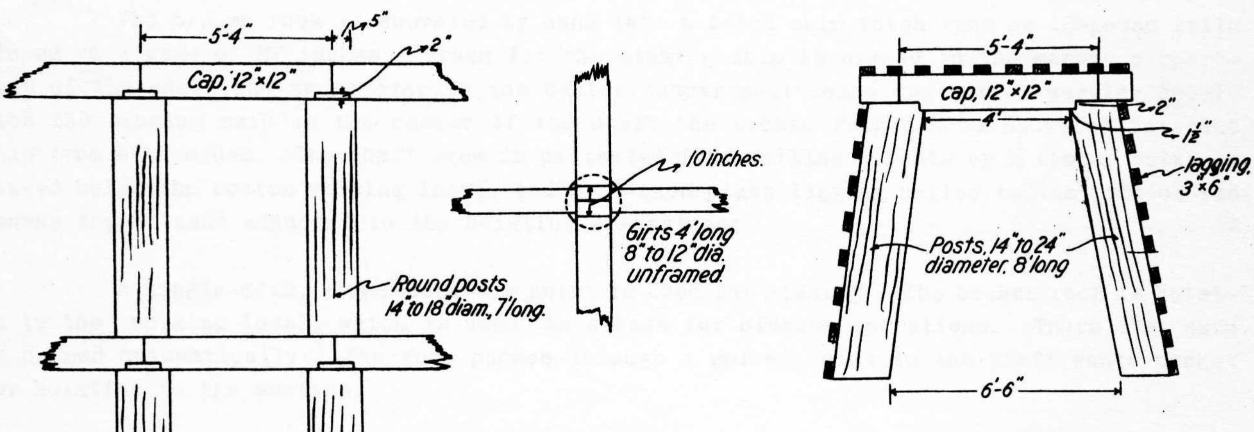


Figure 3.- Shaft timber and framing details.



A- Stope set.

B- Drift set.

Figure 4.- Framing details.

Operation	Time required
Drilling and blasting	1 shift
Shoveling	3 shifts
Placing one set of timber	1 shift

About 80 feet of progress is made per month in sinking the main shaft.

Machines of the jackhammer type with 1-inch hollow hexagonal steel having the double taper cross bit are used in shaft sinking. The lengths of the steel and the corresponding bit gages are as follows:

Length, feet	Bit gage, inches
1-1/2	2-3/8
1-1/2 to 3-1/2	2-1/8
3-1/2 to 4-1/2	2
4-1/2 to 5-1/2	1-7/8
5-1/2 to 6-1/2	1-6/8
6-1/2 to 8	1-5/8

The average shaft round is drilled to a depth of about 5 feet. The holes are loaded with 40 per cent strength gelatin dynamite. About 30 pounds of dynamite are required per foot of shaft. Rounds are fired by means of electric delay detonators connected with the mine lighting circuit of 110 volts. The 32-hole shaft round and the order of firing of the holes are shown in Figure 2.

The broken rock is shoveled by hand into a 1-ton skip which runs on 16-pound rails placed to a gage of 27 inches. Track for the sinking skip is placed in the manway compartment of the shaft and swung over to the center compartment below the bottom working level. With the sinking skip in the center of the shaft the broken rock can be shoveled into the skip from both sides. The shaft crew is protected from falling objects by a timber bulkhead placed below the bottom working level, and by 2-inch plank lagging nailed to the side of the manway compartment adjacent to the hoisting compartment.

A single-drum, compressed-air hoist is used for sinking. The broken rock is hoisted to the working level, which is used as a base for sinking operations. There the skip is dumped automatically. The rock passes through a spiral raise to the shaft waste pocket for hoisting to the surface.

A crew of four men with a shaft boss is steadily employed on one shift for repairing sets and easing heavy ground in the shaft.

Drifts and Crosscuts

Drifts and crosscuts are timbered heavily in order to withstand the pressure exerted by the heavy and sometimes swelling ground. The drift sets are framed with spreading posts and a single cap with lagging resting on the caps and behind the posts. The posts of a drift set consist of round timbers from 12 to 24 inches in diameter and 8 feet in length. The batter of the posts is 2 inches per foot. Caps for the drift sets are 12 by 12 inch timbers 5 feet 4 inches long. Girts are round timbers 8 to 12 inches in diameter. Drift sets are placed on 5-foot centers. Lagging consists of 3 by 6 inch planks cut in 5-foot lengths. No sills are used across the bottom for the posts to rest upon, as in swelling ground the bottom of a drift has in some instances raised as much as a foot per week. If sills were used in ground of this character, repairs to the drift sets would be more difficult and more expensive.

Experience has shown that attempts to lag swelling ground closely result in the bending or breaking of the lagging and in forcing the sets out of position. By leaving openings between the lagging the swelling ground "eases" itself to a certain extent by finding passage through the spaces. This method of lagging also admits of cutting away and removing encroaching ground, thereby preserving the main members of the sets in their proper position. Figure 4-b shows the framing details of the standard drift set used at the Argonaut mine.

Drifts and crosscuts are driven on company account. Two men comprise a drift crew. The two men shovel and tram the ore or rock and then run the drill. The character of the ground varies to such an extent that there is no definite routine of operations in advancing a heading.

Machines of the Leyner type with 1-inch hexagonal steel are used for drilling, mounted either on a cross arm attached to a column or on a crossbar. The lengths of the steel and the bit gages are the same as those used in sinking operations. Rounds are drilled to a depth of 5 feet. Holes are loaded with 30 per cent strength gelatin dynamite and detonated with No. 6 caps and triple-tape fuse. The types of drift and crosscut rounds are shown in Figure 2-b.

The broken rock is shoveled into 1-ton cars and trammed to the shaft pocket or to the nearest dumping place underground.

Raises

Raises are also driven on company account by a crew of two men working together. Raises are driven on the footwall side of the vein and consist of two compartments, a chute and a manway, requiring an opening 6 by 12 feet in the clear. Raise timbering in heavy ground consists of round posts 5 feet long and 14 to 18 inches in diameter, 12 by 12 inch caps 5 feet 4 inches long, and round girts 8 to 12 inches in diameter and 4 feet long. In places where the ground stands well the raises are timbered with stulls and posts. With this method of timbering, a hitch is cut in the footwall to receive one end of the stull; the other end is blocked to the solid with a headboard and the ends of two consecutive stulls are separated by a post. The framing details for the raise square-sets are the same as those used in the stope sets shown in Figure 4-a.

A ladder and timber slide are placed in the manway compartment of each raise. Supplies are hoisted in the raises either by hand or small tugger hoists. The chute is lagged off from the manway with 2 by 12 inch planks.

The routine of operations in driving a raise is about as follows:

First shift

Operation	Time, hours
Preparing to drill	1
Drilling	5
Tearing down	1/2
Loading and blasting	1

Second shift

Operation	Time, hours
Barring down and cutting hitches	2
Hoisting timbers	1
Timbering	4-1/2

Hand-rotated stoper machines are used in drilling. The steel used is 1-inch hexagonal solid with the double-taper cross bit. The changes and bit gages are as follows:

Length, feet	Bit gage, inches
1-1/2	2-1/8
1-1/2 to 3-1/2	2
3-1/2 to 4-1/2	1-7/8
4-1/2 to 5-1/2	1-6/8
5-1/2 to 6-1/2	1-5/8
6-1/2 to 8	1-4/8

The usual raise round comprises 18 holes drilled to a depth of 5 feet. This round is shown in Figure 2-c. Rounds are blasted with 30 per cent strength gelatin dynamite and No. 6 detonators with triple-tape fuse.

MINING

The method of stoping employed at the Argonaut mine is an adaptation of the square-set system and is followed closely by waste filling.

In developing the ore body preparatory to mining, a crosscut is driven from the main shaft station to the vein. From the crosscut, drifts are extended along the footwall. Crosscuts and drifts, 6 by 8 feet in cross section, are timbered with the regular drift sets, and the timber is placed in position close to the working face at all times. When the drift has been extended several hundred feet a raise is driven to connect with the level above. The primary purposes in driving this raise are to afford an additional exit for the workmen in case of necessity and to improve air circulation on the level. A plan of the lower levels is shown in Figure 5.

Silling-out for stoping is done at the top of the first floor above the drift sets. Regular stope sets are used for timbering above the drift, as shown in Figure 6. The reason for silling-out in this manner instead of on the level is that the drifts are easier to repair and keep open. The pressure from the walls acting on the sills is sufficient to hold the sills securely in position so that they will carry the weight of the waste filling if it is necessary to remove a drift set temporarily for repairs or replacement.

In some cases, instead of placing the regular stope sets directly above the drift sets, a system of long caps on stringers is used to support the stope filling, as shown in Figure 7. The blocks for carrying the stringers are placed on the drift-set caps in line with the posts. Stringers are laid on these blocks parallel with the strike of the vein; the stringers in turn support the long caps which extend from wall to wall and are held in position by headboards and wedges. Upon the long caps the stope flooring is laid for holding the waste filling. Above the flooring a change is made to the regular stope sets.

Stoping is carried upward in sections about 100 feet long, or as long as the distance between two consecutive manways, which is usually about 100 feet. Several sections are usually mined at the same time, as one section is several sets lower than the adjoining section. Practically all the vein material in the ore shoot is mined without sorting. No pillars are left.

Due to the conditions that arise in mining in such heavy ground, the manner of removing the ore is varied according to the mine foreman's judgment. Generally only enough ground is removed at a time for standing one set of timber. After a section has been mined one set high across the width of the vein and the length of the 100-foot section another floor is started. Filling with waste is carried on contemporaneously with stoping so that only one floor is open at a time.

Plank floors are carried upward as the stope advances, usually one set below the back of the stope.

Manways are carried up as the stope advances. The gob is held in position at the ends of a section with 2 by 3 inch planks nailed to the sides of the raises adjacent to the waste.

Chutes for drawing ore from the stopes are built in every fifth drift set or at intervals of 25 feet. The ore breaks fine enough in blasting so that it can be drawn from the chutes very readily without hanging up. When possible the ore is diverted into the chutes by wings built of plank in the square-sets. The ore that can not run by gravity into the chutes is shoveled by hand.

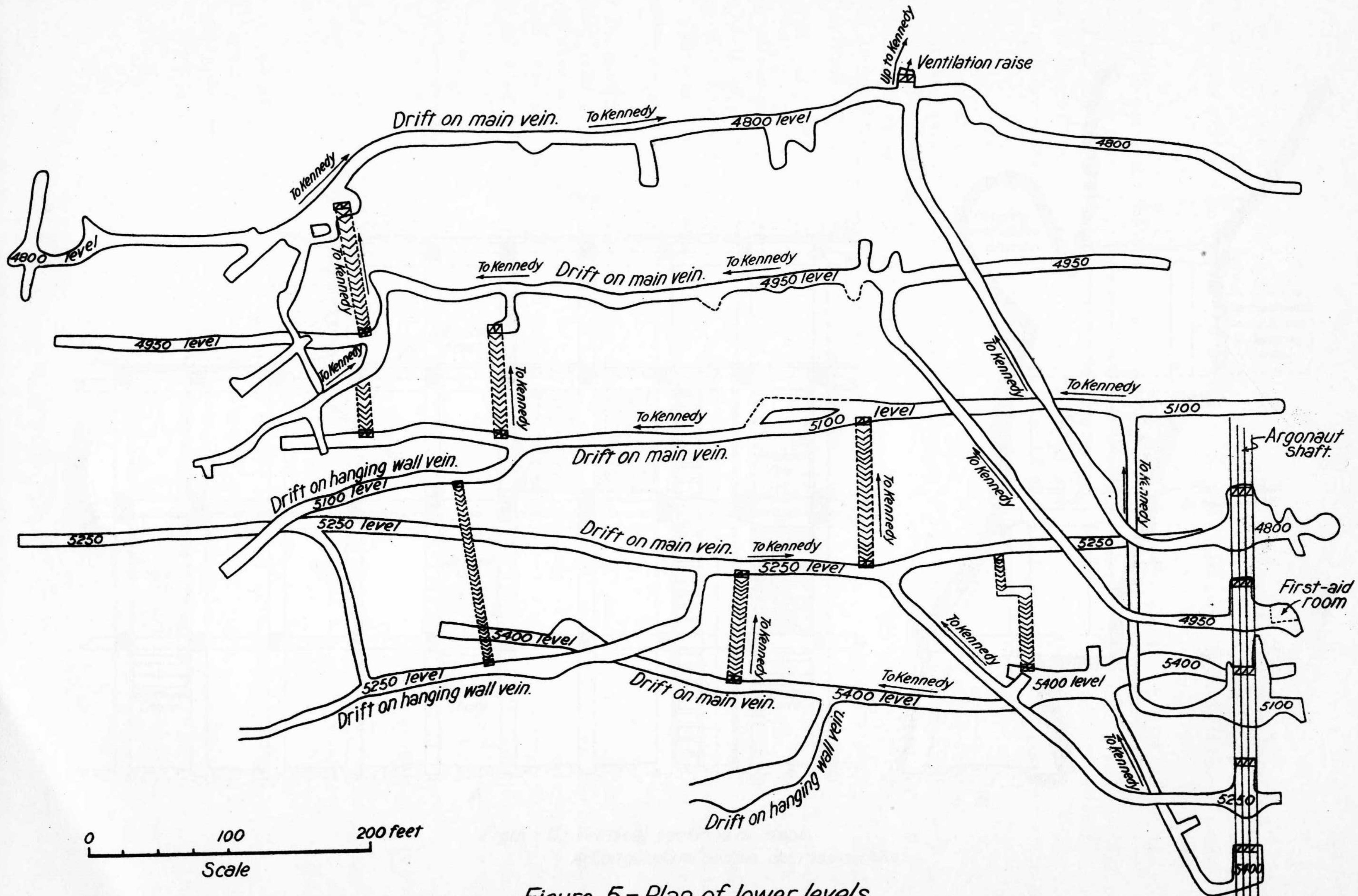


Figure 5.- Plan of lower levels

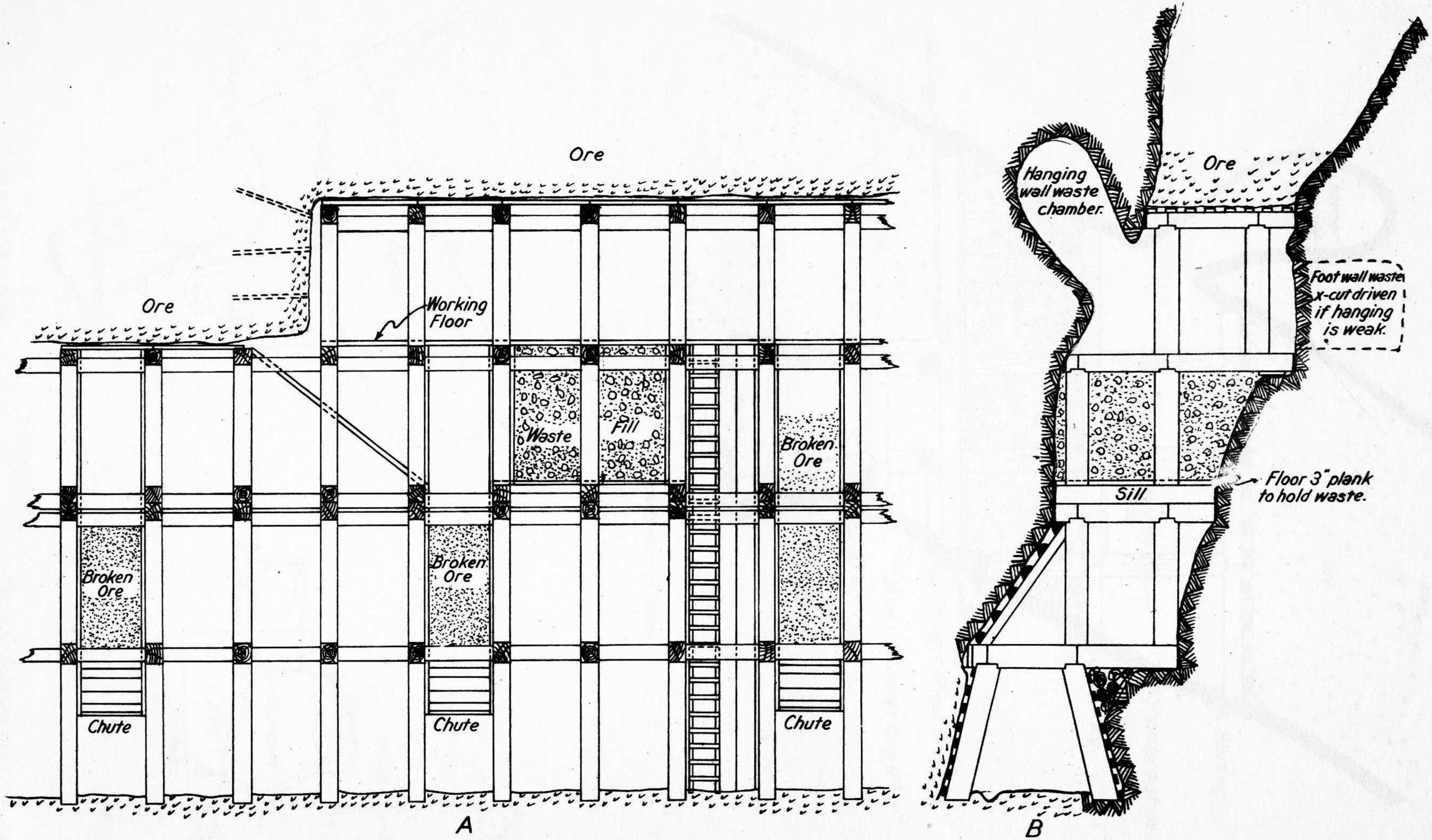


Figure 6,- Vertical sections of stope.
A: Longitudinal section. B: Cross-section.

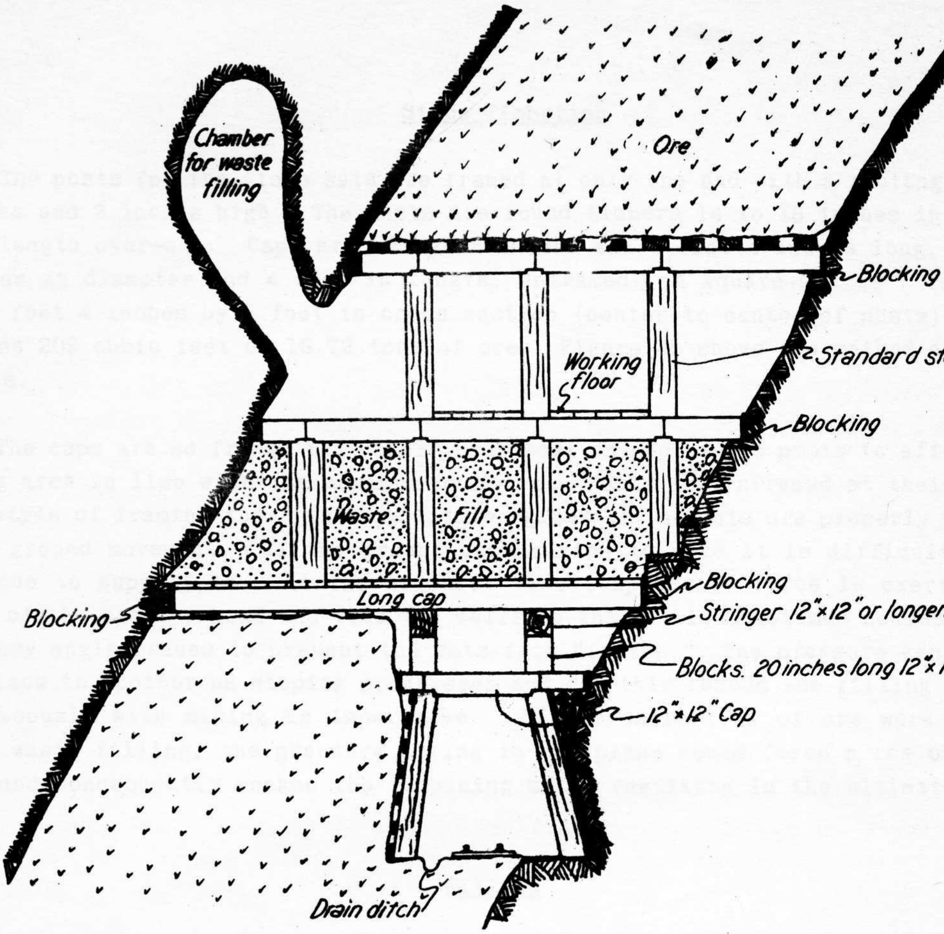


Figure 7.- Vertical section of stope.

Figure 8.- Skip chair

Figure 9.- Automatic control for air-driven pump.

Stope Timbering

The posts for the stope sets are framed at only one end with a rectangular tenon 10 by 12 inches and 2 inches high. The posts are round timbers 14 to 18 inches in diameter and 7 feet in length over-all. Caps are 12 by 12 inches and 5 feet 4 inches long. Girts are 8 to 12 inches in diameter and 4 feet in length, unframed. A square-set is 7 feet 10 inches high and 5 feet 4 inches by 5 feet in cross section (center to center of posts). A standard set contains 209 cubic feet or 16.72 tons of ore. Figure 4b shows the method of framing the square-sets.

The caps are so framed that their ends meet on top of the posts to afford the maximum bearing area in line with the maximum pressure. Posts are unframed at their lower ends. With this style of framing there is very litlle "give" if the sets are properly blocked, thus preventing ground movement. If the ground once begins to move it is difficult, expensive, and dangerous to support it. At the Argonaut mine compressive force is exerted both from the weight of the ore overhead and from the walls so that it is sometimes necessary to put in supplementary angle braces to prevent the sets from "riding." The pressure generally shifts from one place to another as stoping progresses and for this reason the filling of the stopes contemporaneously with mining is imperative. If the extraction of ore were not followed closely by waste filling, the pressure acting in one plane would force a row of sets out of alignment and consequently weaken the remaining sets, resulting in the ultimate collapse of the stope.

Filling

Filling is obtained by driving inclined chambers into the hanging wall, or if the hanging wall is weak and has a tendency to cave, filling is supplied by driving crosscuts into the footwall. The waste is run into the stopes as much as possible by gravity and the final leveling off of the fill is done by hand.

Drilling and Blasting

Machines used in stoping are of the Leyner type, using the 1-inch hollow hexagonal steel. The changes in steel lengths and bit gages are the same as those given in the section on shaft sinking. No standard round is employed in stoping, as the character of the ground varies considerably. For the same reason no routine of operations in stoping can be given.

Most of the ore breaks fairly fine; any large bowlders are broken in the stopes with hand hammers. Grizzlies constructed of old rails are placed over the ore chutes in all the stopes.

Blasting is done with No. 6 detonators, triple-tape fuse, and 30 per cent strength gelatin dynamite.

UNDERGROUND TRANSPORTATION

All ore and rock is trammed underground by hand in 1-ton end-dump cars equipped with roller bearings and cast-steel wheels 12 inches in diameter. The distance from the shaft to the ore body is not great enough to make mechanical haulage profitable. In addition, locomotives would be subject to very severe usage because of the difficulty in maintaining a uniform grade on the track in swelling ground. The average tramming distance on the bottom working level (5,400-foot level) is about 500 feet. Track consists of 16-pound rails laid to a gage of 18 inches. An attempt is made to maintain a track grade of about three-fourths per cent. Ties are 4 by 6 inch timbers 3 feet long spaced on 30-inch centers.

The ore is dumped into shaft pockets having a capacity of about 200 tons. Grizzlies over the shaft pockets are constructed of 40-pound rails with 8-inch openings between the rails.

HOISTING

Hoisting is done in balance with self-dumping skips having a nominal capacity of 72 cubic feet or 4 tons; the average amount of ore hoisted per skip is 7,100 pounds. The skips are equipped with 12-inch cast steel wheels and roller bearings. The wheels have extra wide flanges to prevent derailing. Track in the shaft is of 40-pound rails laid to a gage of 30 inches. The rails are spiked to stringers secured to the footwall wall plates.

The flow of ore into the skips from the shaft pockets is controlled by hand-operated rack and pinion gates. The skip is held stationary in the shaft when being loaded by means of a hook attached to the footwall timber (fig. 8). The hook is raised to engage the front axle of the skip by means of the lever, A. By bearing down on the lever, A, the curved arm, B, raises the hook so as to engage the skip axle. When the weight is taken off the hook by raising the skip the counterweight, C, brings the hook to the position shown in the sketch.

The hoist is situated on the hanging-wall side of the vein, and from the drum centers to headframe sheaves the distance is 300 feet. The slack in the hoisting rope is taken care of by three sets of idler sheaves. The hoist is geared; the pinion has 22 teeth and the spur wheel 108 teeth with 3-inch pitch. The diameters of the gears are 21 and 108 inches respectively. The drums are 8 feet in diameter with 47-inch faces, and they carry 10 layers of 1-1/8-inch diameter, 6 strand 19 wires, hemp-core crucible-steel hoisting ropes. There is a post brake on each drum flange and also brakes on two flywheels on the pinion shaft. Clutches are operated by hand levers.

The hoist is driven by a 500 horsepower, 440 volt, 60 cycle, 3-phase, 440 revolutions per minute at full load, induction motor. On the motor shaft is a 42-inch diameter pulley grooved for 20 turns of 1-1/4-inch hemp rope. The driving pulley on the hoist pinion shaft is 94 inches in diameter. The transmission rope drive is endless in two sections running over 10 grooves each. Each rope is 1,600 feet long and has a tension pulley arrangement mounted on a frame above. A transmission rope lasts from 14 to 18 months.

The motor is controlled by a master switch and liquid rheostat. The hoist is equipped with overwind and overspeed devices. The maximum hoisting speed is about 900 feet per minute.

For several years prior to 1919, hoisting in stages was employed. The second hoisting plant was installed on the 3,900-foot level. At a comparatively small plant like the Argonaut the extra expense of employing three additional hoisting engineers and three skip-tenders, as well as the increased cost of power, is felt, and in consequence stage hoisting was discontinued after 1919. The present hoisting plant has reached the limit of its capacity (5,800 feet inclined distance) and when sinking is resumed, the plan is to install a new hoist with 10-foot drums and 1-3/8-inch rope. With this equipment it is estimated that sinking can progress to 7,500 feet inclined distance and that the ore can be hoisted to the surface in one lift.

WAGE SCALE

About 30 per cent of the underground employees are Mexicans, 10 per cent of various European nationalities, and 60 per cent Americans. The wage scale as of November, 1929, was as follows:

	Wage per day
Engineer (surface)	$ 6.25
Engineer (sinking)	4.75
Miner	4.50
Mucker	4.00
Pipeman	4.50
Pumpman	4.50
Shaftman (repair)	5.00
Shaftman (sinking)	6.00
Skiptender	5.25
Timberman	4.75
Tool nipper	4.50
Topman	4.00
Trackman	4.75
Trammer	4.25

All underground work, with the exception of shaft-sinking, is done on company account. In shaft-sinking the rate paid for a 9 by 17-foot shaft is $45 per linear foot of completed shaft. All tools, timber, explosives, and other supplies are furnished by the company.

VENTILATION

The mine is mechanically ventilated by a 50,000 cubic foot fan, 4 feet in diameter by 3 feet in width, located at the collar of the auxiliary shaft. (See fig. 10 which shows diagramatically the course of the ventilating currents in the mine). The fan is belt-driven by a 100-horsepower, 440-volt, 3-phase, 60-cycle, 575 revolutions per minute motor. The water-gage pressure when the fan is in operation is 2-1/2 inches.

The fan normally exhausts, but can be reversed. In tests the mine air currents have been reversed in six minutes. The fan is so installed at the collar of the shaft that the shaft entrance can be used in case of need for rescue or other purposes.

MINE PUMPING

About 72,000 gallons of water per 24 hours, or an average of 50 gallons per minute, are pumped from the mine. The water is collected on the lower levels and pumped to the main sump for raising to the surface by means of three duplex inside-packed, air-actuated pumps. The pumps are installed at intervals of 300 feet, incline distance; one pump is on each of the following levels: 4800, 5100, and 5400. Each air pump is automatically controlled by a mechanism operated by means of a float in the sump. This automatic control is shown in Figure 9. A float in the sump lifts or lowers the rod, A. Adjustable collars on the rod engage the lever arm, B, and the movement of the lever is transmitted by a toggle to the air valve in the pipe line leading to the pump.

The water is pumped to the surface from the 4800 level in three lifts by three 3-stage turbines, one on each of the 4800, 3900, and 2000 levels. Each turbine is direct-connected to a 75-horsepower, 2200-volt, alternating-current motor.

SAFETY METHODS

The timber used in mining presents a fire hazzrd. This hazard is reduced by precautionary measures taken for the protection of the men underground and of property.

Employees are organized for fire prevention, fire control, and rescue of men underground. A plan of action to be followed in the event of a mine fire is posted in conspicuous places underground (see fig. 10.) The sketch accompanying the plan of action shows the location of the emergency exits, telephones, air bulkheads, fire doors, direction of air currents and location of refuge places.

The main shaft is regularly inspected for conditions tending to increase the fire hazard. The second exit from the mine is also inspected at least once a month.

At each 100 feet in the shaft manway a 50-foot length of hose is kept which is attached to a high-pressure water line. Fire extinguishers of the soda-acid type are also kept in good condition at the same intervals in the shaft. Fire extinguishers are placed at various points underground where they are readily accessible.

Bulkheads of gas-tight material are in place throughout the mine to prevent smoke or gases from cutting off the escape of the men underground.

Mine air currents are positively controlled by the fan located at the collar of the second exit from the mine.

Five sets of approved oxygen breathing apparatus are maintained in good working order on the surface. The apparatus crew renews training at least once each month.

Telephone lines are arranged to provide two means of communication between each working level and the surface, and at the other points in the main shaft and second exit.

A door is provided at the connection between the Argonaut mine and the adjoining property at the 4650 level. Compressed-air and telephone lines are run from each mine to each side of the door.

TABLE 1 - Summary of Costs

Argonaut mine — Month of Sept., 1929
Tons of ore hoisted: 7,800 — Mining method: Square-set and fill

Underground costs per ton of ore

	Labor	Supervision	Drills and steel	Power	Explosives	Timber	Other Supplies	Total
Development	0.139	---	---	0.011	0.011	0.001	0.003	0.165
Mining	1.746	0.052	0.013	0.088	0.148	0.335	0.057	2.439
Hoisting	0.253	---	--	0.109	---	---	0.157	0.519
General underground expense	0.387	0.104	---	0.041	---	---	0.045	0.577
General surface expense	0.201	---	---	0.047	---	0.002	0.041	0.291
Total	2.726	0.156	0.013	0.296	0.159	0.338	0.303	3.991

Note: Above costs are direct costs only.

TABLE 2 - Summary of Costs in units of labor, power, and supplies

Argonaut mine — Month of Sept., 1929

Tons of ore hoisted: 7,800 — Mining method: Square-set and fill

A. Labor (man-hours per ton):		
Development		0.296
Ore breaking and timbering		2.054
Waste breaking and filling		0.347
Ore tramming		0.329
Ore shoveling		0.475
Pumping (underground)		0.092
Shaft maintenance		0.185
General mine maintenance		0.205
Supervision		0.185
Total		4.168
Tons per man per shift underground		1.92
B. Power and supplies:		
Power (total kw. h. per ton)		33.08
Hoisting	9.90	
Air compression	9.02	
Pumping (underground)	6.40	
Ventilation	2.11	
Sawmill	3.81	
Shops	1.45	
Lighting	0.39	
Total	33.08	
Timber (sawed stock bd. ft. per ton)		7.05
(round timber lin. ft. per ton)		1.08
Poles 6 to 10 in. diam.	0.45 lin. ft. per ton	
Poles 11 to 14 in. diam.	0.40 lin. ft. per ton	
Poles 15 to 18 in. diam.	0.18 lin. ft. per ton	
Poles 19 to 24 in. diam.	0.05 lin. ft. per ton	
Total	1.08 lin. ft. per ton	
Explosives (size 1 by 8 in. 30 per cent gel.)		
Sticks per ton		2.75
Pounds per ton		1.01
Other supplies in percentage of total power and supplies		28.5
C. Labor per cent of total cost		72.2
Power and supplies per cent of total cost		27.8

Argonaut shaft downcast.
Muldoon shaft upcast.

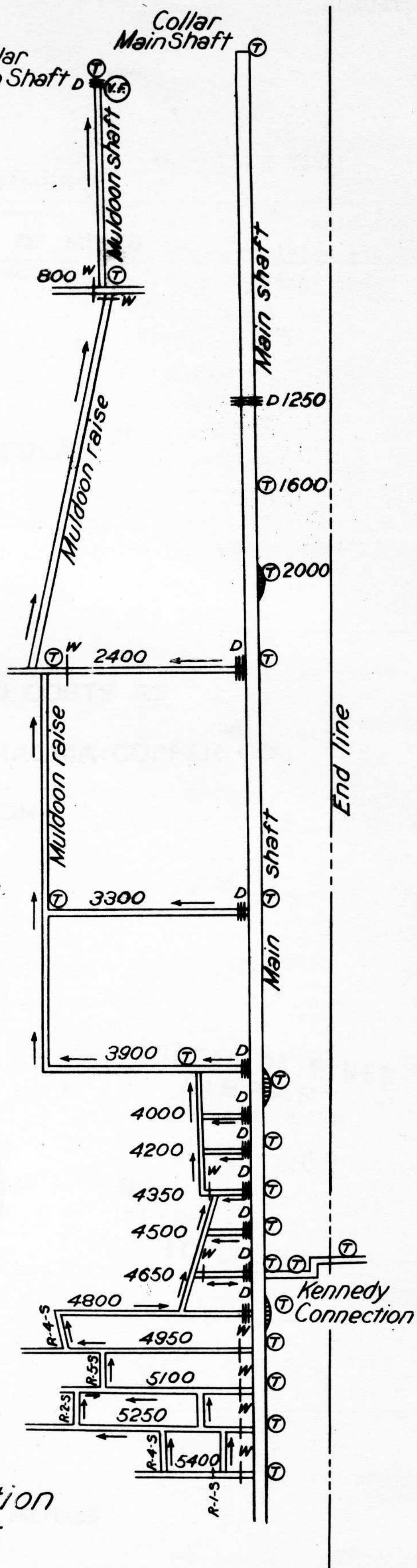
Sept. 15th 1929

- Iron door
- Wooden door
- Telephone
- Ventilation fan
- Water column by-pass 2000 L.-3950 L.-4800 L.

Fire hose and extinguisher on each level in main shaft.

Valve to let in surface water at collar of main shaft.

← Exit.



In case of fire.

1. Phone hoist engineer stating location of fire.
2. Notify shift boss.
3. Notify men in all working places.
4. Shift boss to account for all men and be ready to go to 4650 rescue chamber or up main shaft as case may be.

Figure 10.- Vertical projection Argonaut shaft.