THE LATOUCHE CAVING SYSTEM

a Thesis

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by

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CONTENTS

THE LATOUCHE CAVING SYSTEM

Introduction

The Latouche plant of the Kennecott Copper Corporation is located on Latouche Island in the Prince William Sound district of Alaska, sixteen hundred miles northwest of Seattle, or two thousand miles by the steamship lines. The island is situated eighty miles southwest of Cordova and fifty miles east and slightly south of Seward, the nearest townsof any size. (Fig. 1.) The camp, lying on the west side of the island, is on a small bay of the well protected Latouche passage, between Latouche Island and Elrington Island. (Figs. 2, 3, 4 and 5.) Seattle is the main supply point for Alaska.

History

The first claims were staked on Latouche Island July 4, 1897, by Andrew K. Beatson, although stone hammers that had apparently been used by the Indians, found buried in the soil near the ore body, indicated that the island had long been a source of supply of native copper and paint pigments for the Chenega tribe.

Fig. 2

Wireless Point at Latouche. (X) Location of camera for Figures 3, 4, & 5. Latouche Passage in foreground.

Fig. 3

Winter scene at Latouche. Mill and dwellings in foreground.

Fig. 4

Power house, mess house, bunk houses add office at Latouche.

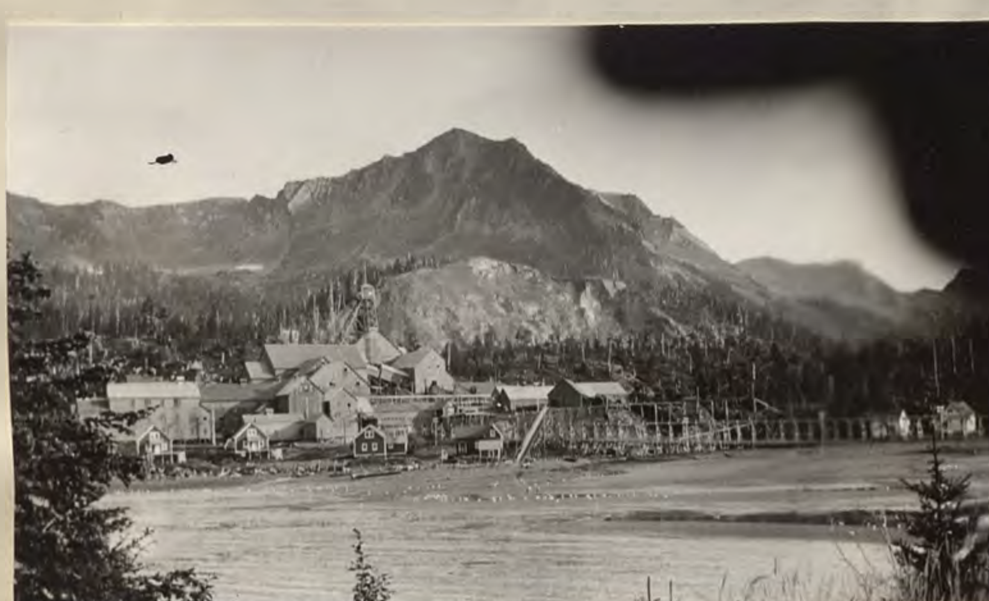

Fig. 5

Mill and Main shaft head frame. Open pits in the background.

A trial shipment of ore made in 1899 was followed by other small shipments until 1904, when regular shipments were commenced. The ore was first quarried from the hillside. Later tunnels were driven on two levels, thirty feet and one hundred and twenty feet (main level) below the working floor and the ore broken into raises run from them. In 1910 the mine was taken over by the Kennecott Copper Corporation. Several mining systems were tried with varying degrees of success until the present caving system was developed in 1922-1923. The open pits furnished the bulk of the ore until this time.

Previous to 1915 all ore was hand-picked and shipped to the smelter. In this year a seven hundred-ton, all flotation mill was built, which was enlarged to 1500 tons in 1918. In 1922 a four-cell retreatment plant was added.

The original Beatson property consisted of fifty-five claims, of which nineteen are patented, and a mill site. In 1923 the Girdwood mine of the Latouche Copper Mining Company, twelve claims and a mill site, adjoining the Beatson on the north, was purchased. The mineral tracts are the usual fifteen hundred by six hundred feet lode claims.

Geology

The country rocks at the Bonanza mine are narrow alternating bands of graywackes and slates of the Orco group, believed to be of early Mesozoic age (R. S. Capps, U. S. G. S. Bul. 605).

The slates predominate to the west of the mine and the graywackes to the east. The ore body, roughly lenticular in shape, is in a shear zone of the graywacke and slate. The ore occures partly in fractures and partly as replacement of the country rock.

The lense is about eight hundred feet in length with a maximum width of about three hundred feet. On the lower levels the south end is split by a horse of waste which pinches out at its top a few feet below the main level. The two branches of the ore body, formed by this split, are referred to as the hanging wall ore body and the footwall ore body. The general strike of the ore body is North 12° East, with an average dip of 65° to the West. The hanging wall of the main ore body, as well as the hanging wall of the footwall ore body, is marked by a major fault, associated with a hard band of pyrrhotite. A poorly defined fault marks the footwall in some places. Minor faults and slips, together with numerous calcite stringers and clay seams, traverse the ore body in every direction.

Chalcopyrite is the main ore mineral. It is intimately associated with pyrrhotite in varying proportions ranging from almot pure chalcopyrite to almost pure pyrrhotite. With these two minerals but occuring in smaller amounts, is pyrite and quartz. Traces of the secondary copper minerals, malachite, covelite and native copper are found at or near the surface.

General Items that Influence Methods of Mining

The climate is very mild owing to the modifying effects of the Japanese current. The temperature ranges from 16 degrees Fahrenheit above in winter to 75 degrees Fahrenheit above in summer. The rainfall is very heavy, exceeding 140 inches a year, of which about sixty per cent is the winter snow. There are occasional heavy rains in which as much as twenty-four inches has fallen in three days. The heavy snowfall makes it necessary to cover the tram lines with snow sheds. In spite of the heavy precipitation the climate is very healthful. There is little or no sickness in the camp.

The buildings of the camp are located only a few feet above high tide. The highest point in the mine workings is about four hundred feet above sea level and the lowest two hundred and fifty feet below.

Water at a good pressure is piped to the camp through wood stave pipes from lakes above the camp. This supply, while ample for all camp needs, is too irregular for water power. Due to the mildness of the winters, very little trouble is caused by freezing of the pipe lines. Water from the mine, as well as salt water, has been tried in the mill, but neither has proven as satisfactory as fresh water.

Timber is cut on adjacent islands and floated to the camp, where it is framed in a small saw mill operated by the company. While excellent for the mine and all rough uses, this lumber is not of a high enough grade for permanent buildings, lumber for which is shipped from the States.

Underground labor is 95% European, who also predominate in the surface crews, with exception of mill and power house operators, where Americans and Scandinavians are employed in about equal numbers. The large ebb and flow of labor, 250% turnover yearly, makes an extremely flexible mining system necessary. A full crew in the winter may, in a few weeks, in the spring be reduced to less than one-third of its original strength, when the men go to the placer camps and fishing fleets where higher wages are paid. All labor is non-union.

The camp is favored with excellent transportation facilities, lying on a well protected harbor, directly accessible to ocean going vessels. It is a port of call for the boats of both the Alaska Steamship Company and Admiral Steamship Company. The Alaska line has one boat a week on the regular run, with freighters calling whenever there is cargo. The Admiral line has two boats per month. Boats stop both on their way west and on their return trip. The average sailing time from Seattle to Latouche is six days, which, however, may be extended to nine or ten days, during the summer rush, when the boats have many extra cannery stops. All company freight is handled by the Alaska line, a subsidiary of Kennecott Copper Corporation.

A wireless plant operated by the company makes it possible to keep in touch with the States and to transact business without undue delays.

Exploration, Sampling and Estimating Methods

Exploration

Exploration is carried on by cross cutting, drifting, raising and diamond drilling. Cross cuts are depended upon for most of the information as to the extent and character of the ore, with drifting and raising to supplement it. Diamond drilling is used to locate ore, rather than give any definite information concerning it. Inasfar as possible the exploration work is laid out in such a manner that it will form part of the development system when mining is started.

Sampling

The mineral, Chalcopyrite, occurs as small masses and stringers in both the graywacke and slate. The differences in hardness between the mineral and the gangue, as well as in the gangue itself, which may vary from unfractured graywacke to badly crushed slate, as well as the spotty character of the ore, makes sampling extremely difficult. Large channel samples, five inches wide and two inches deep are found to give the best results. No grab samples are taken. Samples are taken with a small air hammer (Fig. 6) such as the Ingersoll Rand Company's Little David Chipper. The moils are made from chisel blanks. The use of the air hammer not only re-

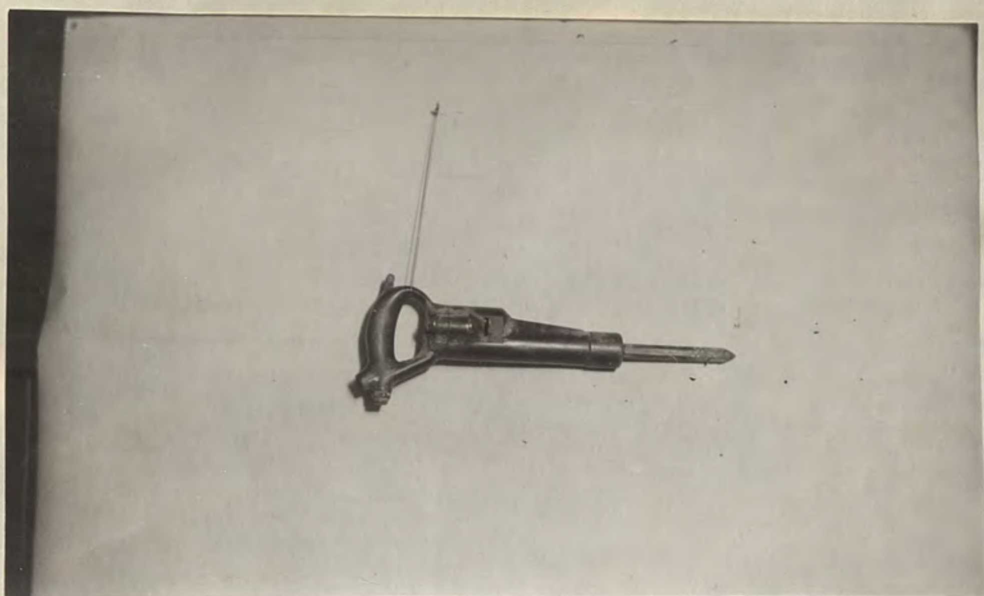

Fig. 6

Sampling hammer.

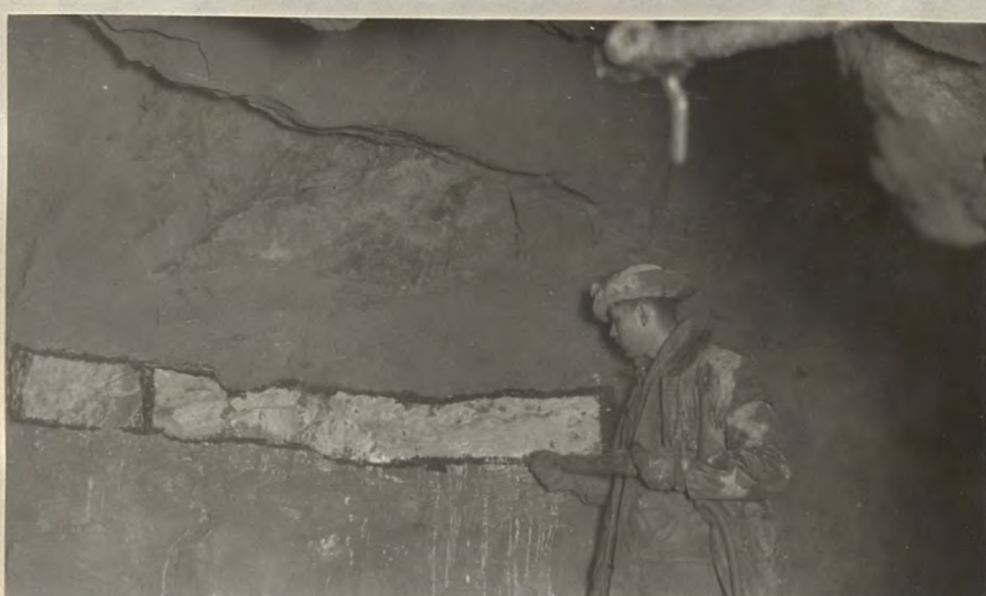

Fig. 7

Sampling in cross cut.

duces the cost of sampling, but partly eliminates the personal factor. Workings are sampled as they are being driven so that an air line is always available, and a double connection, carried by the sampler, enables him to work without interfering with the miner. A sample sheet is seldon used as large chunks of matter foreign to the sample sluff off as the channel is being cut. The sampler's helper catches the cuttings in a powder box and watches to see that a uniform quantity is obtained from all parts of the channel. The surface is cleaned by cutting a shallow channel before the regular channel is cut.

Four types of samples are taken, drift, crosscut, hanging wall raise and footwall raise samples. All types have for an object the cutting of the ore in the plane of the level or at right angles to the bedding plane. Drift samples are taken across the back of the drift at five-foot intervals. Crosscut samples (Fig. 7) are taken five feet in length along both sides of the cross cut. Samples from opposite sides serve as checks on each other. Samples are cut uniformly four feet above the track level to avoid overlapping. Raises up to fifty degrees are sampled. The socalled footwall raises are raises starting in the ore body and running toward the footwall, making but a small angle with the dip of the vein. They are sampled on both sides from back to bottom (Fig. 8) at right angles to the dip of the bedding at five-foot intervals. Hanging wall raises start in the ore body and run toward the hanging wall, cutting the bedding approximately at right angles. Samples in these raises are cut in the same manner as they are cut (Fig. 9) in a cross cut. Two samples taken from the same interval or from opposite sides of a cross cut may not check by two or three per cent. However, a resample of an entire cross cut will usually check the original sampling within one-tenth of a per cent.

In diamond drilling sludge samples are taken for every five foot of hole. The core, which is very badly broken, is examined and then included with the sludge for assaying.

Estimating Tonnage and Grades

The mine is divided into stopes seventy feet wide and pillars thirty feet wide running from foot to hanging wall. All estimating is done by stopes. The assays on a level, within the limits of a stope, are averaged by weighting them to determine the average assay for the stope at that level. Two levels are then averaged together, in ratio of their respective areas,

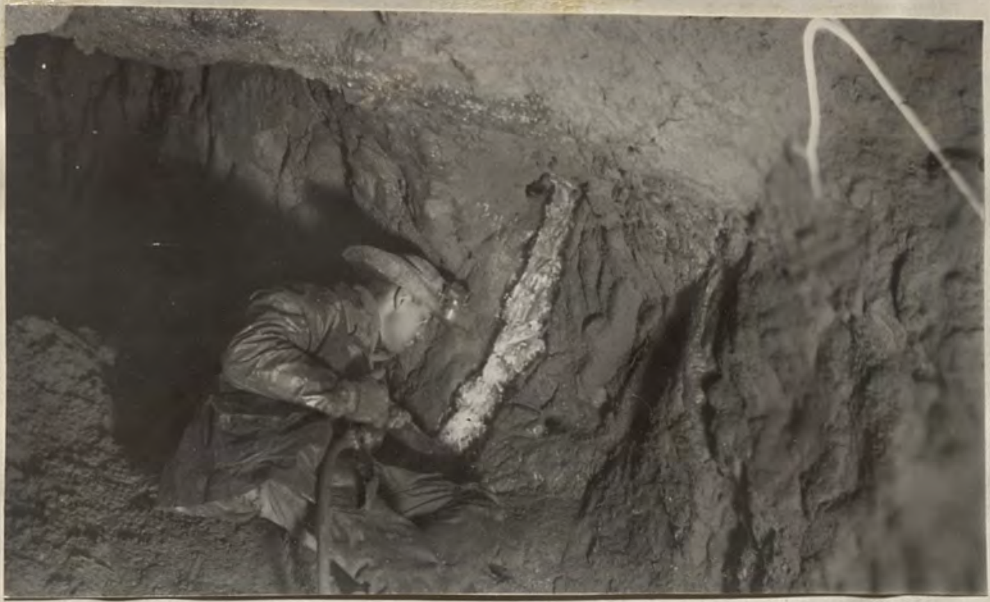

Fig. 8

Sampling in footwall raise.

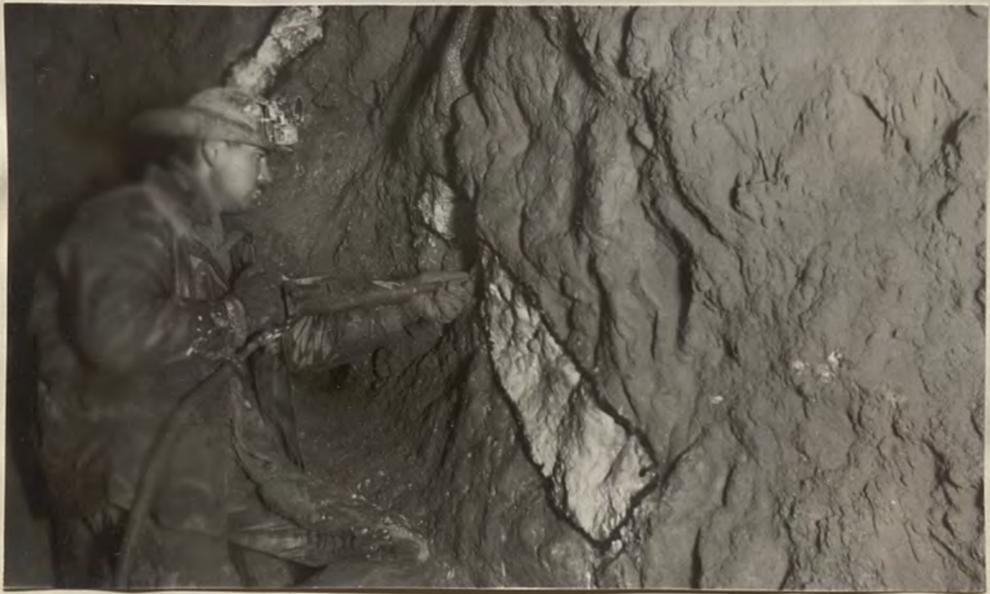

Fig. 9

Sampling in hangingwall raise.

to give the average for the block between them. The average grade of the stope is obtained from the weighted averages of the various blocks in it, and of the mine from the weighted averages of the stopes. The ore reserve table is so constructed that the tonnages and grades may be read either by levels or by stopes.

Tonnages are estimated on a base of twelve cubic feet of ore in place and eighteen cubic feet of broken ore to the ton. Results obtained by milling well sampled blocks of ore show that the assay averages are too high. A ten per cent reduction is made to cover this. A further lowering of the grade is made by allowing ten per cent for dilution, which, as the tonnage is not increased by this amount, more than compensates for any loss of ore in mining. No definite checks have been obtained, but such results as have been obtained, seem to justify these factors.

General Underground Features

General Features

The ore body which is roughly lenticular in shape, although not well defined as to foot wall, lies along the side of a small hill. The foot wall extending along the summit, the hanging wall along the base, two hundred and fifty feet lower. The economic length of the ore body is eight hundred feet, the maximum width three hundred feet, and as yet the depth has not been determined. The south end of the ore body being split by a horse of waste on the lower levels necessitate separate stopes being carried in the foot wall and hanging wall branches which, however, join a few feet below the main level and continue above as one stope.

The alternating bands of graywacke and slate together with the numerous slips and seams make the ore very blocky. There are no faults of any importance, except the one which marks the hanging wall, beyond which mineralization has not extended. The hanging wall composed chiefly of slate is very weak, the footwall in which graywacke predominates is somewhat stronger.

Numerous small areas of waste are included in the ore zone, but are not of sufficient size to justify any attempt to exclude them, with exception of the large horse which splits the south end and which is more in the nature of a rib between two ore bodies.

The angle of repose of dry ore is about 50° which is reduced to less than 45° in the presence of the usual flow of water. No difficulty is encountered in drawing ore through the chute raises which are run at 40°.

The mine temperature ranges from 32° Fahrenheit to 40° Fahrenheit with a relative humidity of about 60%, which varies with the outside atmospheric conditions. Powder gas is the only gas present in the mine and it, during the shift, is localized to the bulldozing levels. The coldness of the mine, together with the abundance of fresh air, makes ideal working conditions from which a high labor efficiency results.

Mine Openings

The main shaft through which all ore is hoisted is located at the mill about 900 feet northwest of the center point of the ore body, on the hanging wall side. Underground tramming is preferable to surface haulage, due to the heavy winter snow fall which necessitates snowsheds as well as to the roughness of the surface between the mine and the mill. The shaft, 360 feet deep, has three compartments, each 5 x 5 inside the timbers. It is equipped with two skips and a cage. No manway is necessary as there are many connections between the lower levels and the main level and between the main level and the surface. The skips dump into the ore bins of the coarse crushing plant. By means of a gate, waste can be hoisted in the skips and dumped into a waste bin in the head frame. From this bin the waste is conveyed by aerial tram to the dump. Ore pockets are located below the 200 foot level and below the main level. A 65° incline shaft, called the "201 Manway," connects the main level with the 200 foot level at the north end of the ore body. It is a two-compartment shaft provided with an air hoist for materials and a manway. On the south end of the ore body another two-compartment shaft provided with an air hoist and manway, called the "70 Manway", connects the main level with the levels above.

The main level is opened up by a tunnel 970 feet long from the portal to the ore body. This tunnel cuts the main shaft about 200 feet from the portal and 60 feet below the collar. On the 200 foot level (200 feet below the main level), a similar transportation cross cut connects the main shaft with the mine workings. On both levels the transportation tunnels pass north of the ore body to connect with drifts in the footwall, from which transportation cross cuts cut the ore body. Short cuts are provided in the form of hanging wall drifts which cut the transportation cross cuts only a few feet from the hanging wall. The main tunnels and footwall drifts are not affected by the mining operations but the hanging wall drifts soom become unusable when the stopes near their level.

Mining Methods Formerly in Use

The first mining at Latouche was in the form of quarrying along the hillside which was soon converted into open pitting by driving a transportation tunnel and raising to the quarry floor, a method which is still in use. The present system is to drive a bulldosing level fifty feet above the transportation tunnel on which grizzlies are placed. From the grizzlies raises are run to the surface and the ore milled into them. It gives a relatively low cost per ton as well as a high tonnage per man shift, but is limited to depth as well as giving a poor recovery of ore along the hanging wall, which is, however, recovered by the present system of mining when the stopes are brought through to the surface. Some trouble is caused during the winter months by the broken muck freezing in the pits, but this is largely overcome by flushing with salt water.

Some of the richer ore on the hanging wall was mined by square setting. It is, however, too expensive an operation to be applied to an entire ore body. As the ore outcrops on the crest of a small hill, wasts for filling would have to be hoisted for the upper floors. Although interfering somewhat with the present mining system, the old square set stopes serve to form a timber mat on the hanging wall.

Shrinkage stoping was abandoned as unprofitable and dangerous. The numerous fractures and clay seams causing large blocks to cave from the roof, limited this method to narrow stopes requiring an excessive number of stulls, the majority of which were lost in the broken ore causing trouble when they reached the chutes. Kill stoping was found to have the same disadvantages as shrinking stoping, but due to the arch of the back could be applied to larger areas. Both systems left from forty to fifty per cent of the ore in pillars which was either lost or recovered at an excessive cost.

Necessity for a Change

As the open pits, which had supplied the bulk of the ore, neared their limits of depth, it became necessary to devise a system of working the deeper ore.

As has previously been stated the underground mining methods that had been tried had proven unsatisfactory. Square setting gave a high recovery of ore, but the cost prohibited its application to the entire ore body. Shrinkage stoping gave a very low recovery of ore together with a high cost due to the small areas that could be opened up. Rill stoping had the same disadvantages as shrinkage stoping but larger areas could be opened up.

The usual forms of caving could not be applied to this ore body as its tendency to break in large blocks made it necessary to shatter the ore before it could be drawn. The comparatively flat dip of the ore body makes it necessary to have a closer control over the drawing of the broken ore than is afforded by the usual caving system in order to avoid excessive dilution.

It was from the rill stopes that the present caving system was developed, the early stages of which were described by Stephen Birch in volume LXXII of the transactions of the American Institute of Mining and Metallurgical Engineers. The following is a description of the method as it was finally worked out. In form it resembles a large shrinkage stope in which the rounds are drilled from raises instead of from the muck pile and in which a system of grizzlies replace the ordinary chutes.

Mining Operations

Actual underground operations, aside from prospecting, are divided into three general operations -development, stope preparation and mining or stoping.

Development

As has been previously stated the mine is divided into stopes 70 feet wide and pillars 30 feet wide running across the ore body from footwall to hanging wall. Each stope is divided into sections 35 feet wide, called the north stope and the south stope. The pillars to the south of the stope are given the same number as the stope; as for example, 201 north stope, 201 south stope and 201 pillar. (Fig. 12). In the case of the south end of the ore body, where it is split by the horse of waste, the corresponding stopes in the footwall and hanging wall ore body are given the same number and identified by calling them the footwall or the hanging wall stope. This avoids confusion of numbers above the main level where the ore body is not divided by the horse.

A two hundred-foot vertical lift or section is best adapted to the system. From the 200-foot level to the main level being one section and from the main level to the surface another or rather a part of one, which in most cases, due to the small quantity of ore remaining from the open pits, is worked through as part of the 200-foot level section. Development work on the section below, 200 to 400-foot level, may be started but very little mining can be done until the section above is worked out. The transportation level of the upper section will form the entrance level for the section below.

The 200-foot level (Fig. 10) is the transportation level located 200 feet below the top of the section to be worked (main level). It consists of a 7 x 7-foot drift located in the footwall about 200 feet from the edge of the ore body and connected with the main shaft by the haulage tunnel. From the footwall drift cross cuts are driven at 100 feet intervals across the ore body ten feet south of the center line between the north and south stopes. The curves connecting these cross cuts with the footwall drift have a fifty-foot radius, while curves in the transportation tunnel have a 100-foot radius. The track on this level is 24" gauge with 35-pound rails.

Fifty feet above the transportation level is the 150-foot sublevel (Fig. 11) which is the bulldozing level. In form it is similar to the 200-foot level. A 5 x 7-foot footwall drift, 80 feet from the ore body, is connected to the main and 200-foot levels by the 201 Manway. From the footwall drift, 5 x 7-foot cross cuts are driven along the center lines between the north and south section of the stopes. On this level the curves have a radius of 35 feet. The track which is used for transportation of supplies only, is formed of 16-pound rails with a 24" gauge.

Short 5 x 7-foot connection drifts connect these cross cuts with the grizzly chambers, which lie to the north and south of the cross cuts opposite each other. The grizzly chambers are located on the socalled center lines of the stopes (Fig. 12), which are fifteen feet from the edges of the stopes and twenty feet from the center line between the stopes. The grizzlies are spaced about sixty feet apart, this distance being determined mainly by the number of points of draw needed to control the broken ore in the stopes, and in a minor way by the cost. As the grizzly pillars will be recovered by the lift from below, the value of the ore contained in them is not a factor that enters into the spacing of them.

The grizzly chambers are 5 x 7 x 24 feet in length. The raises are run from the chutes on the north side of the transportation cross cuts on the two hundred-foot level (Fig 12), branching about ten feet above the chute; one branch going to the grizzly in the north section of the stope and the other branch going to the corresponding grizzly on the south.

The grizzlies (Fig. 13) are in two sections, each section 5 x 12 feet. They are formed by 110-pound railway steel with 16-inch space between the flanges of the rails, which are inverted. These rails are embedded in 12 x 16-inch stulls at either end and supported in the center by a 12 x 16-inch stull. The rails are held apart by spreader bars. The stulls at either end are protected by half-inch plates spiked to them. Rails have been found to be better adapted to this use than heavy pipe, which was at first used, as it is more rigid, less subject to wedging of the rock and giving a better working floor for the bulldozers, as well as having a longer life, easier to salvage and reuse, and cheaper. Single-end grizzlies were first used but they were soon replaced by the double-end grizzlies which have twice the number of points of draw for the same amount of development. work.

The raises on either end of the grizzly chambers are run so that the toe of the muck pile will reach to the center of each section (Fig. 13). leaving a 12-foot clearance in the center. Care must be taken in starting these raises at the right elevation, for if they are too high the muck will flood the grizzly; while if they are too low, they will be difficult to draw. The center line of the 40° raise (5 x 5) strikes the grizzly 7'-6" from the center between sections. The clearance space in the center of the grizzly gives the bulldozer room to pull the larger boulders out of the way until he has time to blockhole them.

As it is only six feet from the back of the chamber to the bottom of the stope, the bulldozer can easily reach larger boulders hanging up in the raise to place powder or even in the case of very large blocks to drill them with a stoper without endangering himself.

Development in the stopes proper (Fig. 12) consists in running raises at 40° from each end of the grizzlies which meet the raises coming from the grizzlies on either side. From a point six feet above the grizzlies, 40° turnback raises are run, meeting over the center of the grizzly. These 40° raises are called undercutting raises.

Mining raises are run from the undercutting raises to the main level, where they connect with short entrance drifts from the cross cuts of that level. The mining raises are spaced about fifty-five to sixty feet apart. (Figs. 12 and 14). The minimum number of raises necessary is determined so that they will not be over sixty-five feet apart. They are then spaced proportionately, so that each raise has the same amount of ground to break. The exception being the raise nearest the footwall which is never more than twenty-five feet from it.

The development on the main level consists of 5 x 7-cross cuts, driven from a 7 x 7-foot drift in the footwall along a line five feet south of the center line of the pillar Fig. 12). This offsetting of five feet is to allow raises, driven on the centerline of the pillar, to break into the side of the cross cut rather than into the center. Entrance drifts from the pillar cross cuts are driven to the raises in the south section of the stope north of the pillar and to the raises in the north section of the stope south of it. On this level the cross cuts are located in the pillar rather than on the center line between the north and south section of the stopes because, as has been previously stated, it is planned in most cases to continue the stope above the level until it reaches the open pits, which are but a short distance above, rather than start a new lift which would not be economical. As the main level was opened up before the present mining system was developed, for the purpose of open pitting and square setting, it is but poorly adapted to the present system. Use is made of the old working when suitable, but experience has shown that it is poor economy to attempt to alter the system to fit the old workings, as the efficiency of mining depends upon the proper spacing of the various workings.

Mining Details

In the small cross cuts and drifts the Ingersoll-Rand B.C.R.W.430 jackhammer is used with the J.C.12 mounting, and 7/8-inch hexagonal steel is used with these machines. They are used on either horizontal or vertical 3-inch single-screw bars. In these workings, which are seldom on contract, the miner works alone or with a mucker. Standard 5-foot rounds of 13 holes are usually drilled. The monthly advance is from 130 to 150 feet.

In the larger drifts and cross cuts and for harder ground, the 248 Leyner using $1\frac{1}{4}$-inch hollow round steel is used. Ordinarily two machine men work together and no helper is employed. The standard 7-foot round has 15 to 19 holes with an average monthly advance of 210 feet.

All raises are run 5 x 5 feet. Ingersoll-Rand C.C.11 stopers, with 1-inch quarter octagon steel, being used. No timbering is done in these raises with the exception of an occasional set of lagging, where the back is bad. Light 4 x 4 stulls are used for the platforms, which are shot out every round. Ladders made of 4 x 4 -inch oak with iron rungs, hung on jackhammer steels sunk in the footwall, are used for running the raises. The miner works alone in the raise with a helper for every two or three raises. Nine-hole, five-foot rounds are used. Good raise miners average a five-foot round per shift and even three-rounds every two shifts, for a short distance above the level. After the mining raises break through to the level above, the heavy ladders used while they are being run are removed and permanent ladders with slide board and air hoist are installed.

In running the chute raises from the 200-foot level to the grizzlies, the raise is run before the grizzly chamber is cut. It is run at an angle, never less than 45°, until 8 feet below the level of the grizzly and then vertical in order to leave a shoulder. The entrance drifts are then broken into the raises and the grizzly chamber cut and the floor belled out. The grizzly is installed before the undercutting raises are run, for the double purposes of safety and to give a means of access to the raises.

Stope Preparation

Stope preparation is the intermediate step between development and mining. It consists of undercutting the stopes. At a point 6 feet above the back of the grizzly chamber the undercutting raises are widened out until they reach the full width of the stope at the point where the turnback raises start. They are carried at full width until they reach the apex between grizzlies. The turnback raises are then undercut.

The weakness of the back causes continuous sluffing or caving while the stope is being undercut. A narrow strip along the face is fairly solid and a few stulls make it safe for the miner. The faces are reached by coming through the uncut raises, it often being necessary to come down the mining raises to avoid passing through the undercut areas. Small pillars are left through the undercut, particularly along the line between the north and south sections of the stope. These pillars are drilled while the stope is being undercut and blasted when the undercut is completed. The back will then cave until an arch is formed or the undercut filled.

CC11 stopers are used for this work. Vertical rows of 5 or 6-foot holes are drilled with 3 holes to the row. The rows are about 3 feet apart, arranged so that they will break into the raise or into the previous round. Two miners work near each other in the undercuts with no helpers.

Mining

After the undercut is completed the stope is ready for mining operations (Fig. 14), which consists of two steps: (1) cutting of a working chamber, (2) drilling and blasting the main round.

At a point about 25 feet above the back of the stope the working chamber is cut, 15 to 18 feet square and a platform placed over the raise below.

From the working chamber long holes are drilled in all directions (Fig. 14). These holes are carefully spaced and of such a length that they will break along the pillar line. The holes are chambered, then loaded and fired by electricity. The round in one raise is blasted at the same time as the round in the corresponding raise in the other section. All the rounds in a stope are either prepared and blasted at the same time, or in a series, working from the hanging wall toward the footwall. The back in the center of the stope is carried higher than at either wall to strengthen it. Blasting is more for the purpose of shattering the ore than to break it down. After the series of rounds has been blasted across the stope the next series is started 25 feet above the new back. A round usually gives from 30 to 35 feet of vertical breaking.

When a stope reaches within about 30 feet of the surface the remaining ore is broken by holes drilled from the surface. In the case of a lift being brought through into the bottom of a stope, full of broken ore, it would either be abandoned and allowed to cave through; or the final round, drilled from the entrance level, would include long up-holes. After the impracticability of shrinkage and rill stopes had been proven by experience, though the latter gave the best results, it was decided to modify the rill stopes by drilling the rounds from raises. Raises were run at about thirty-foot intervals, parallel to the foot and hanging wall. Working chambers, similar to the present form, but smaller, were cut directly above the back; muck of the stope forming the floor. Rounds of ten or twelve-foot holes were then drilled from them. The spacing between the raises was widend and the size of the working chambers and length of the holes increased until the present system was developed. These early stopes were only thirty-five feet in width with no pillars, alternating stopes being mined first, while the others were left as pillars to be recovered later.

Details

The working chambers are cut with stopers and jack hammers. After a chamber is cut, a platform is placed over the raise below it. The long holes are drilled with Ingersoll-Rand DDR13 76-pound jackhammers, using $1\frac{1}{4}$-inch hexagonal steel. The jackhammers are unmounted, a fork being used for support. The rounds vary from 24 to 40 holes depending upon the hardness and blockiness of the ore to be shattered. Two miners work to a chamber with no helpers.

<u>Pillars</u>

After two stopes are mined through to the surface or to the bottom of the lift above and before the ore in them can be drawn, the pillar between is mined. The broken ore in the stopes on either side supports the unbroken ore of the pillars.

The development plan of the pillars is the same as that of the stopes, except that there is only one line of grizzlies and raises instead of two. The chute raises to the pillar grizzlies are cut from the south side of the 200-foot level transportation cross cuts (Fig.12). The entrance drifts to the grizzlies are either driven from the stope grizzlies or from the cross cuts (Fig.11). While the pillars are being undercut a substantial pillar is left between the undercut and the broken ore which is blasted when the undercut is completed.

The actual mining of the pillar is carried on in much the same manner as mining of the stopes. The working chambers, are, however, smaller as the pillar cannot be weakened too much and the holes are shorter as they have the stopes to break to. Mining in the pillars is much more difficult than in the stopes. They are more subject to running, due to the poor support, often caving in large blocks before they can be shattered by blasting. As it is a slow settling of the block there is little danger to the miners, but the blocks give trouble when they reach the grizzlies.

Drawing Ore

The operation of drawing ore is probably the most important feature of this system, as the success of the entire system depends upon careful manipulation. This work is done by a separate crew of bulldozers under a bulldozing boss. It may be divided in two divisions; (1) drawing ore to make room for mining, (2) drawing the ore after mining has been finished.

Drawing Ore to Make Room for Mining--While stoping is being carried on, before the pillars are mined, only enough ore is drawn from the stopes to make room for blasting. As the ore will, if given room, soon start caving and continue until all available space is filled. No drawing takes place until the rounds are ready to fire. The amount to be drawn is estimated on the ratio of 12 to 18 (cubic feet of rock in place to cubic feet of broken rock), and the chutes pulled accordingly. These estimates are of course supplemented by watching the rate of draw from above. If too much broken ore is drawn, the unshattered ore above the round will cave in large blocks and often run into the pillar enough to weaken it. If not enough space is provided, the efficiency of the round will be lessened.

The same operation takes place while the pillars are being mined but with a greater degree of uncertainty; as it is almost impossible to estimate the amount of ore that it is necessary to draw, in order to give certain space, on account of the ore running in from the stopes on either side, so that the maximum opening is in the center, decreasing to zero on either side. While the pillars are more subject to running and settling than are the stopes, the lack of side support makes the hanging up of shoulders impossible.

Drawing Ore After Mining is Completed--As the broken ore must be left in the stopes on either side of a pillar to support the pillar while it is being mined, the bulk of the ore cannot be drawn until at least two stopes and the pillar between them have been finished and then only in a limited degree in the stope next to the unmined pillar. As has previously been stated, no mat is placed between the overburden (hanging wall) and the ore; and as the footwall sluffs as the ore is drawn away from it, great care must be taken to draw the ore evenly to avoid mixing it with the waste. The hanging wall and footwall chutes are drawn first, forming a dome of the broken ore, in which the dip of line between the broken ore and the waste does not exceed 40°. All chutes are then pulled evenly until waste appears at hanging and footwall, at which time they are abandoned and draw continues in the others until each in turn shows waste. While this point can be determined very closely by occular inspection, it is checked by assays of grab samples from the grizzlies. From 300000 to 500000 tons of broken ore will remain in the stopes, unavailable, until a lift is completed.

The ore is very favorable for this form of drawing as it breaks with more or less conchoidal fracture, which lessens the inclination to roll and channel, except immediately above the point of the draw, allowing the ore to settle evenly with a minimum inclusion of waste.

Advantages of the Present System

1. The system in use at present has the advantages of the usual caving system but can be more closely controlled.

2. The weakness of the ore and weight of the walls is an asset and not a liability as with the older system. The hanging wall, which it is impossible to support, is allowed to come in and aids in crushing the ore.

3. The large quantity of broken ore in the stopes makes this system very flexible, enabling the mine to run through the summer months when labor is scarce with a very small crew. Men can be taken from development and mining and put on bulldozing so that the output of the mine is uniform, which it would not be in systems where the output is directly proportional to the ore broken. During the winter months, when labor is plentiful, development and stope preparation can be pushed far enough ahead to take care of the summer labor scarcity.

4. The relatively large tonnages obtained per working place reduces the number of stopes required to produce a given tonnage, which lessens the amount of development and stope preparation work that must be done ahead of mining, thus reducing the capital investment.

5. The net profit to be obtained by this present system is greater than by any of the older systems.

6. The tonnage per man per hour is higher than in the other systems and fewer skilled men are required, or rather there is a greater opportunity to train and utilize unskilled labor.

7. Over ninety per cent of the ore is recovered.

8. Development work per foot of ore is reduced to a minimum and being systematic, a maximum efficiency and correspondingly low costs are obtained for this work.

9. Very little timber is used except on transportation levels.

10. The regular form of the workings aids in the control of ventilation.

11. Accident rates are reduced by having the men always working above the back, where they are not endangered by sluffing.

Explosives and Blasting

Forty and sixty per cent powder is used, manufactured by the DuPont Powder Company. For raise work, gelatine is used; 60 per cent for the cut holes and 40 per cent for the others, because of the greater ease in handling. Sixty per cent gelatine is also used for cut holes in drifts and cross cuts. Forty per cent Red Cross is used for all other work.

Fuse and caps are used for small rounds, while the large round firing is done with electric delays and magneto.

Timbering

The company operates a small saw mill which also serves as a timber framing shop. Timber is cut near the beach on Latouche and adjacent islands and rafted to the bay on which the mine is located. Logs are carried from the beach to the saw mill by an incline tram, which delivers them to the saw carriage. Sawed timber is used almost exclusively underground as the cost of sawing is less than the cost of procuring timber of the proper size. Quantities of standard sets are framed and stored in the yard. For special jobs a sketch is made by the engineer, showing the dimentions of each piece and giving it a number when the timber is framed. Each piece is numbered corresponding to the sketch. A sketch is also given to the foreman and the timber boss.

The only timber used in the raises is the staging used while driving them and the stulls for the permanent ladders, except an occasional set of lagging. A few stulls are used in the undercuts to make the back safe along the working face.

On the transportation levels the sets are of 8 x 10-inch timbers, 7 x 7 feet in the clear with a 6-inch spread at the bottom. Sets are 5 foot center to center on both straight away and curves. They are lagged as the ground requires with 3 x 10-inch lagging. Sets on the grizzly levels are 5 x 7 feet in the clear with a 6-inch spread at the bottom, set 5 foot center to center. 8 x 10-inch timber is usually used but in many places 6 x 8-inch is heavy enough.

The saw mill and storage yard are at the same elevation as the main level so that the timber can be delivered at the shaft, the manways or at the head of any raise without transfering it. No timber is stored in the mine.

Traming and Haulage

Transportation of ore takes place only on the main transportation levels, 200 feet apart vertically.

The chutes through which the ore is drawn from the grizzlies are lined with one-half inch sheet iron. They are 6 feet wide with a 4-foot clearance from chute floor to head block. An arc type gate is used with chute boards to prevent overflow. Pockets cut in the back of the drift enables the loaders to work above the chute. The loading crew consists of two men, who serve one or more trains. They remain at the chute while the motorman takes the train out. A bulldozer at the shaft switches the train and takes care of the oversize on the grizzly

Granby type 5-ton, side dump, cars are used, which automatically dumpwhen passing over a camel back at the skip pocket. six 5-ton car, hauled by a $4\frac{1}{2}$-ton Baldwin Westinghouse storage battery motor, make up a train.

Sixteen cubic feet end dump cars and twanty cubic feet rocker dump cars are used for development work.

Underground Storage and Dumping

The ore trains dump directly into two skip pockets through a 16-inch grizzly which catches any slabs that passed the grizzlies on the grizzly level. A switch thrown between the locomotive and the first car causes the train to run on a track six inches closer to the camel back than the one on which the locomotive runs, so that the cars pass over it.

The skip pockets are of 250 tons capacity each lined with steel rails. The ore is drawn into measuring pockets, then loaded into the skips. Air cylinders operate the gates controlling the skip pockets and measuring pockets.

A charging room for the locomotive is located at the shaft station and sufficient yard room is provided for the cars.

Hoisting

Men and supplies are hoisted in a single-deck cage 4'-4" x 4'-10", inside dimensions, equipped with spring safety dogs. The cage is operated by a Coeur d'Alene Hardware and Foundry Company hoist, having a 36 x 36-inch drum. It is driven through a single gear reduction, by a 100-horse power, 440 volt motor. A three-quarter inch plow steel cable is used.

The man hoist, for safety reasons, is located in a separate building a hundred feet in front of the main hoist room. The hoist is equipped with overspeed and overwind controls, and an automatic cut out switch is located in the head frame.

Ore is hoisted in two six-ton skips, operating in balance at a speed of six hundred feet per minute. The hoist is a double drum Wellman-Seaver-Morgan geared electric hoist, with 60" x 42" drums, driven by a 150-h.p. 440 volt motor. One and one eighth-inch plow steel cable is used. Brake and clutch are operated by air cylinders.

Pumping

Although located near and below the level of the sea, there is, as far as can be detected, no seepage from it. The greater part of the water comes into the mine through the mine openings, rather than from seepage, although in places this is quite heavy. The greater part of the water which comes from the open pits is drawn off through the main level. Three Gould triplex pumps, geared to 440 volt motors, take care of the water from the lower levels. A seventy-gallon per minute pump, located at the 201 manway, and a 275-gallon per minute pump at the shaft lift from the 200-foot level, and an eighty gallon per minute pump on the 300-foot level keeps the shaft clear.

Air Compression

Air is supplied to the mine at eighty pounds pressure by three compressors, a Chicago pneumatic 1750 cubic foot compound, an Ingersoll-Rand 600 cubic foot and an Ingersoll-Rand 300 cubic foot. The first twoare direct connected to 2200 volt motors and the last is belt driven. The 300-cubic foot compressor is used to supply air to the mill and for operating the air gates at the shaft loading pockets between shifts and to keep up pressure in the line between shifts.

Ventilation

The constant blasting on the grizzlies throughout the shift generates large quantities of smoke which must be quickly cleared from the level so as not to retard the drawing operations. This is the most difficult ventilation problem encountered. Gas from the regular mining and development operations can, in the time between shifts, be easily disposed of. The rather good natural ventilation was carefully studied before installing the artificial system and the latter was so laid out that it would receive the maximum help from the natural system. An exhaust fan of 40000-cubic foot per minute capacity at about 3-inch water gauge pressure, direct connected to a fifty horse power 2200 volt motor, located at the collar of the number 70 manway, helps the natural upcast of this shaft. The air passes down through the main shaft, through the transportation cross cuts, up the manways connecting each transpotation cross cut with the corresponding cross cut above it on the grizzly level, through the cross cut to the footwall drift, through to the ventilation raise to themmain level, through the main level footwall drift to the 70 manway and out to the surface. Ventilation doors located at the entrance to each cross cut allows the air to be directed where it is needed. Bulldosing is usually being done in only one or two stopes, so that the entire flow of the air can be directed through the cross cuts in use, very little being used on the main level.

Lighting

Transportation levels, shaft stations, shafts, loading pockets, manways, powder and supply rooms are lighted by electricity. A 110 volt A.C. current is used, the same as light circuit of the camp. Safety chambers on the transportation levels are marked by a red light. Small carbide cap lamps are used almost entirely by bosses and men alike, with only an occasional lamp of the larger type. All men are required to carry candles for emergency use.

Signals

The common pattern of electric pull bell is used at the shafts. Hand lines are located in each compartment for emergency or when working in the shaft. An electric switch with a light at the entrance of each cross cut, located so that the motor man can throw it in passing, shows whether there is a train on the main line or not.

Telephone

All stations on the main and auxiliary shafts and several other places underground are connected by telephone with the hoist room, compressor room, foreman's office amd electric shop. Through the electric shop the underground system can be connected with the surface line.

Record of Unit Production

The total labor cost including hoist men, mine electricians and mine mechanics is 59.8%.

Contracts and Bonuses

Drifts and cross cuts, with exception of the short entrance drifts to the grizzlies, and to the tops of the mining raises, are run on contract basis. The contractor furnishes powder, caps and fuses, purchased from the company at cost. Mucking and traming to the first siding, never over 200 feet, may or may not be included in the contract. Timbering and ditching are usually done by the contractor but are paid for on a different contract. Track and pipes are carried to the face by the company.

Raises are run on a bonus system. Bonus is paid on each foot advanced over three feet per day, averaged every 30 days. (Bonus on all footage over 90 feet in 30 working days). No bonus is paid if the miner quits before the raise is completed.

A bonus is paid for drilling long holes in the stopes on footage over 30 feet per shift. This is averaged over the number of days required to drill out a round.

All other work is on days pay.

Production

The following figures are based on dry tons of 2000 pounds, and are the monthly averages based on 5 months in which the plant was operated at normal capacity.

Tons milled per month	48216
Tons mine production--	
Open pit	7248
Development	1316
Stope preparation	1097
Mining	38555
Total	48216
Tons broken--	
Open pit	7248
Development	1316
Stope preparation	1097
Mining	114288
Total	123949
Tons broken ore remaining in stopes	75733

The following figures are on the basis of eight hours per shift and should be slightly higher for actual working time as no allowance has been made for the time lost in going to and from the working place.

Class	Tons per Man per Hour	Man Hours per Ton
Open pit--		
Miners	10.47	.096
Total	9.59	.104
Stopes--		
Miners	12.07	.083
Total	11.91	.084
Stope Preparation--		
Miners	1.48	.675
Total	1.24	.806
Development--		
Miners	.47	2.130
Total	.25	4.000
All mine labor	3.74	.267

Wage Scale

Miners	$ 5.25
Timbermen	5.50
Trackmen	5.25
Pipe men	5.25
Hoist men	5.75
Skip tenders	5.00
Motor men	5.25
Loaders	4.75
Helpers	4.75
Muckers	4.75
Labor	4.75

Classification of Labor

Class	Per Cent Employed
Bosses	4.35
Engineers	2.17
Miners--Stope	28.28
Open Pit	2.17
Stope preparation	2.17
Development	8.70
Helpers	5.07
Muckers	2.90
Timber men	2.90
Skip tenders	4.35
Nippers	1.45
Powder men	1.45
Drill repair men	.72
Blacksmiths	2.90
Hoist men	3.62
Motormen	3.62
Loaders	5.80
Bulldozers	7.70
Pipe men	2.17
Track men	2.17
Electricians	.72
Mechanics	.72
Miscellaneous	2.90
	100.00%

Units of Supply

Explosives

Class--	Lbs. per Ton of Broken Ore
Development	.07
Stope preparation	.05
Stoping	.15
Bulldozing	.02
Total	.29
Open pits	.34

Timber

Class--	Feet B.M. per Ton Ore Broken
Development	.011
Stope preparation	.006
Mining	.001
Total	.018

Power

Class--	H.P. Hrs. per Ton Ore Broken
Mining (Compressed air)	
Machines	1.46
Tugger hoists	.15
Hoisting	.97
Haulage	.24
Pumping	.46
Ventilation	.37
Lighting	.14
Total	3.79

Cubic feet of compressed air per ton of ore broken.................... 1100

Cost of Mining

Labor	58%
Supplies and maintenance	42%
	100%

The cost per ton of the old methods was from 50% to 400% higher than the cost per ton of the present system.

Disposition of Ore

The ore hoisted from the mine is dumped directly into the bins of the coarse crushing plant at the mill. The concentrate, after being filtered and dried, is hauled to storage bins on the dock in rocker bottom dump cars by a motor. The concentrates are drawn through chutes on to a belt conveyor, which loads them in freighters for transportation to the Tacoma smelter.

Safety and Welfare

Training in first aid and mine rescue work are given to all employees. No safety engineer is provided, this being part of the duties of the engineering department. A well equipped hospital with a doctor and nurses are provided with free treatment for employees and their families.

Three, four and five-room modern houses are provided for the families, and rooms and a mess for the single men. A department store is operated at about cost. A laundry and a small hotel run by private individuals complete the camp.

Recreation matters are handled by the employees' club. A club house with pool and billard tables, bowling alleys, reading room and entertainment room is maintained by the club. A tennis court is also provided. Moving pictures are shown twice a week. The camp is excellently located for outdoor sports such as hunting, fishing, boating and all winter sports.

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