Mining at Giant Yellowknife

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Introduction

THE GIANT YELLOWKNIFE property is on the west side of Yellowknife bay, Great Slave lake, N.W.T., some 600 air miles north of Edmonton. This paper deals with the underground development and mining of the complex system of orebodies which have produced, in the first fifty-six months of operation (May, 1948, to December, 1952), 652,464 tons of ore with an average grade of 0.80 ounces of gold per ton (1).

The mine has been developed from three vertical shafts designated *A*, *B*, and *C*. Figure 1 shows the positions of these openings with respect to the known ore-bearing zones and the surface plant.

A shaft was sunk to a depth of 522 feet in 1945-46, primarily as a prospect shaft for investigation and development of the East Zone orebody. Drifting was carried out on the 200- and 325-foot levels. Before this development had been completed it was clear that the funds immediately available made it imperative to get revenue from production as soon as possible. By the beginning of 1946, the remarkably high-grade character of the ore in the present *B* Shaft area had been established by surface drilling, and the decision was made to obtain initial production from this source. Since known orebodies at shallow horizons were to be developed quickly, the choice of a suitable rock outcrop for the shaft was something of a problem. Largely governed by the danger of tying-up exceptionally rich ore in a shaft pillar, *B* shaft was sunk, during 1946, at the south end of what was known to be a north-plunging system of ore shoots, and levels were established at the 100- and 250-foot horizons. Subsequently, the shaft was deepened for the 425-, 575-, and the 750-foot levels.

Before mill construction was begun, the collar of *C* shaft was excavated at a site adjacent to the crushing plant. This opening was planned as a central production shaft, and for development of the South and Central *ASD* zone. Sinking was started in November, 1949, and by February, 1952, the 750 level haulage connection with *A* and *B* shafts had been completed.

At the present time, *A* and *B* shafts are used as service and ventilation openings and all muck is hoisted through *C* shaft.

Development

Shafts

'A' Shaft

This shaft extends to a depth of 793 feet. It is 6 ft. 8 in. by 17 ft. 8 in. outside dimensions and is divided into three equal compartments, 5 ft. by 5 ft. 4 in. measured inside the timbers. Two compartments are equipped with cages and the third is a combined manway and pipe compartment.

One sump placed just below the 450 level has a capacity of 33,000 U.S. gallons. Pump capacity from this sump is 150 U.S. gallons per minute. An air-lift pump, placed in the shaft bottom sump, discharges the drainage water from below the 450 level into the 750 level ditch, which leads to *C* shaft.

'B' Shaft

B shaft is 779 feet deep, and both shaft and compartment dimensions are the same as for *A* shaft. A 2-ton skip is installed in No. 1 compartment, No. 2 is a cage compartment, and No. 3 is a manway and pipe compartment.

There are two sumps with a combined capacity of 90,000 U.S. gallons located immediately above the 425 and 750 levels. Two pumps can discharge water to surface at the rate of 200 U.S. gallons per minute.

Two loading pockets installed below the 250 and 575 levels are not now in use. Until February, 1952, all ore from the *B* Shaft workings was hoisted through *B* shaft and trucked a distance of 3,000 feet to the crushing plant. Since then, the ore has been by-passed to the 750 main haulage and trammed to *C* shaft.

'C' Shaft

C shaft, a five-compartment shaft through which all ore and surplus waste are hoisted, has been sunk to a depth of 1,029 feet. Figure 2 shows the dimensions and arrangement of the several compartments. Shaft sets were fabricated from B.C. fir and are spaced at 6-foot centres.

Pipe lines consist of a 6-inch air line, a 3-inch water supply line, a 4-inch pump discharge line, and a 4-inch drain line. In addition to these, a 3-inch air line delivers high-pressure air directly to the loading pocket when the main air line is used to blow smoke between shifts.

Two sumps, each with a capacity of at least 50,000 U.S. gallons, are located on the 575 and 950 levels. Pump capacity at the 950 sump is 450 U.S. gallons per minute against a total head of 450 feet, and at the 575 sump it is 200 U.S. gallons per minute against a total head of 650 feet. Two spare pumps are available, each with a capacity of 190 U.S. gallons per minute at a total head of 700 feet.

One hoisting compartment is equipped with a skip-over-cage combination of aluminum alloy, in balance with a steel skip in the second compartment, the capacity of each skip being 60 cubic feet. When the shaft is deepened, for exploitation of lower levels, a large hoist will be installed, with skips of 80-cubic-foot capacity. The present hoist will then service men and supplies,

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(1) For other phases of the Giant operation reference should be made to the immediately preceding papers by PITCHER, P. N., *The Giant Yellowknife Operation,* and by BROWN, C. E. G., and DADSON, A. S., *Geology of the Giant Yellowknife Mine,* and to the paper by GROGAN, K. C., *Milling at Giant Yellowknife,* which follows.

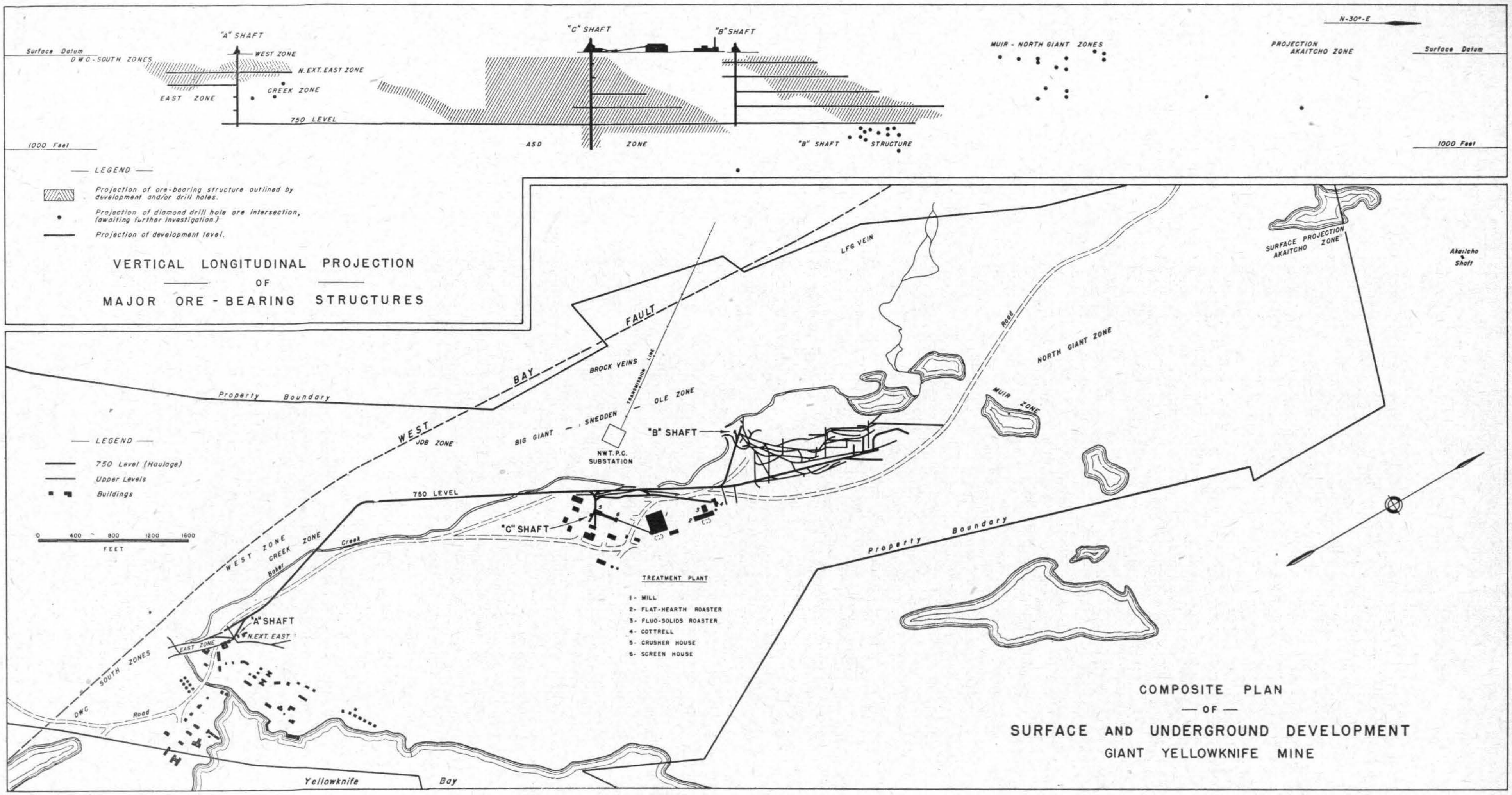

"A" SHAFT
"C" SHAFT
"B" SHAFT
N-30°-E
Surface Datum
D.W.C.-SOUTH ZONES
WEST ZONE
N. EXT. EAST ZONE
CREEK ZONE
EAST ZONE
750 LEVEL
1000 Feet
ASD ZONE
"B" SHAFT STRUCTURE
MUIR - NORTH GIANT ZONES
PROJECTION AKAITCHO ZONE
LEGEND
Projection of ore-bearing structure outlined by development and/or drill holes.
Projection of diamond drill hole ore intersection, (awaiting further investigation.)
Projection of development level.
VERTICAL LONGITUDINAL PROJECTION
OF
MAJOR ORE - BEARING STRUCTURES
WEST BAY FAULT
LFG VEIN
SURFACE PROJECTION AKAITCHO ZONE
Akaitcho Shaft
Road
NORTH GIANT ZONE
MUIR ZONE
BROCK VEINS
TRANSMISSION LINE
OLE ZONE
BIG GIANT - SNEDDEN
NWT. P.C. SUBSTATION
"B" SHAFT
Property Boundary
JDB ZONE
LEGEND
750 Level (Haulage)
Upper Levels
Buildings
0 400 800 1200 1600
FEET
750 LEVEL
"C" SHAFT
WEST ZONE
CREEK ZONE
Baker Creek
TREATMENT PLANT
1- MILL
2- FLAT-HEARTH ROASTER
3- FLUO-SOLIDS ROASTER
4- COTTRELL
5- CRUSHER HOUSE
6- SCREEN HOUSE
"A" SHAFT
N. EXT. EAST
EAST ZONE
SOUTH ZONES
DWC
Road
Yellowknife Bay
COMPOSITE PLAN
OF
SURFACE AND UNDERGROUND DEVELOPMENT
GIANT YELLOWKNIFE MINE

Figure 1.

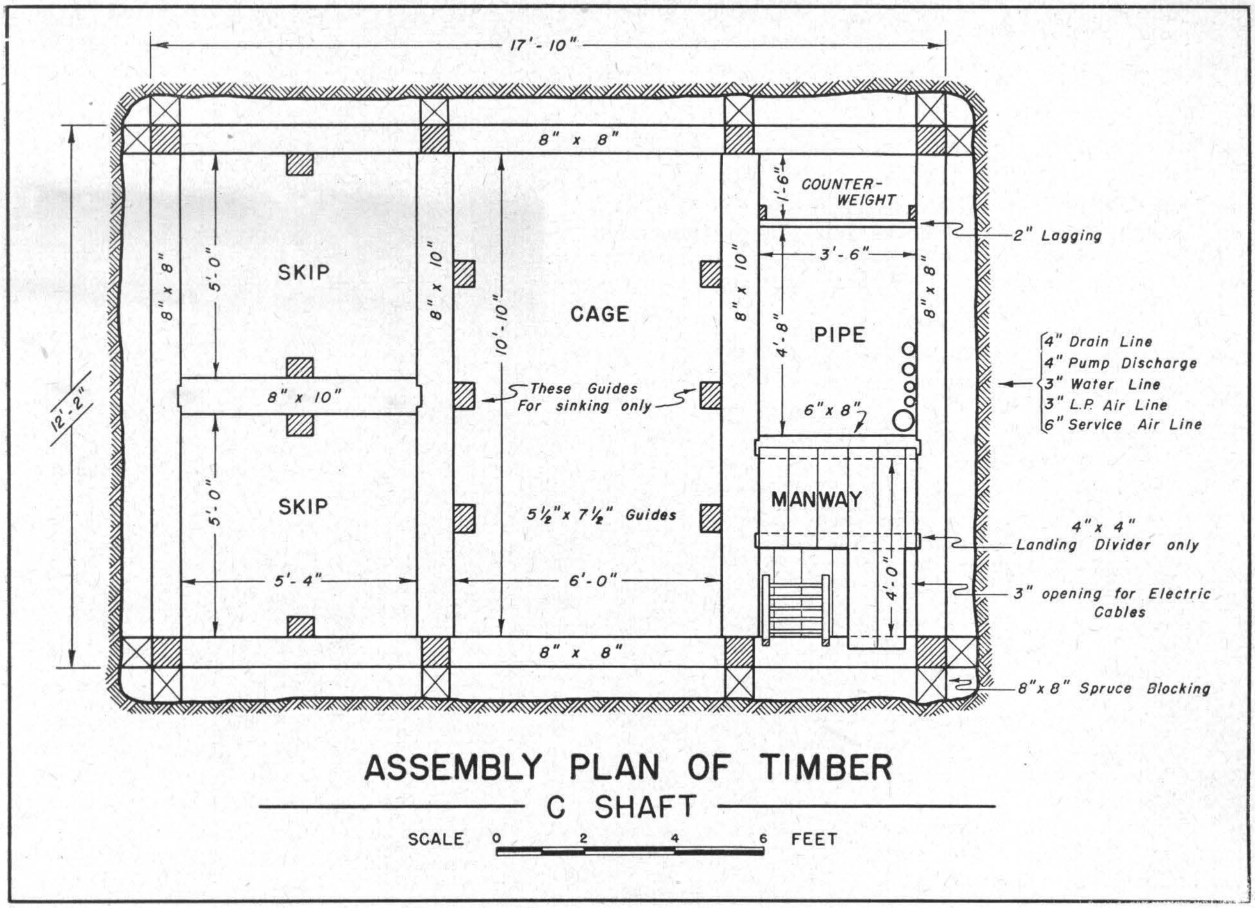


Figure 2.

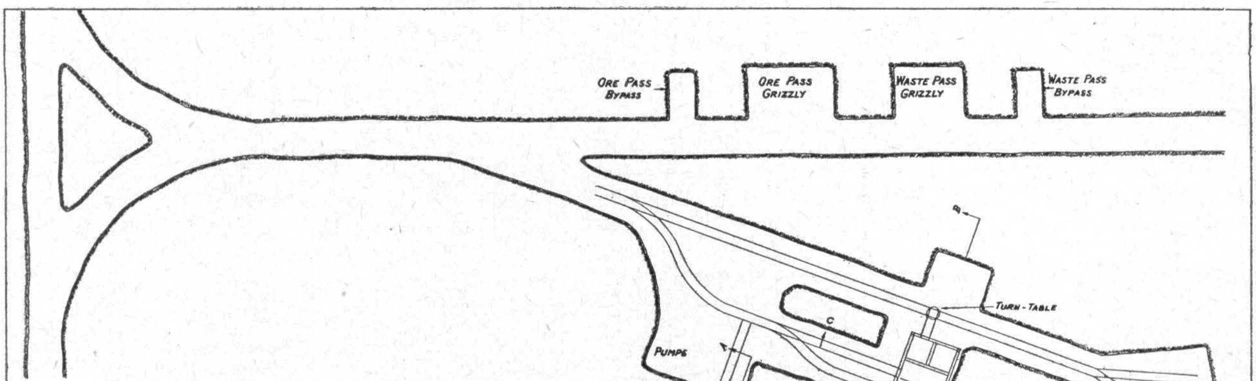


Figure 3.

with a large cage in the now unused central compartment.

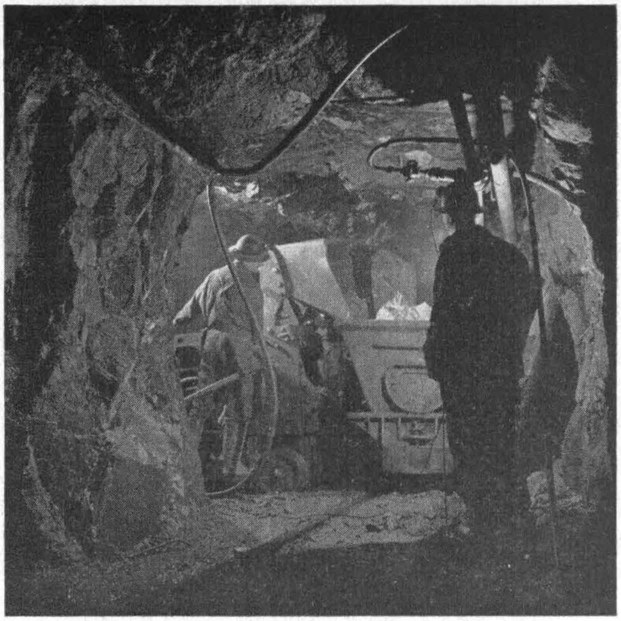
An air-operated measuring and loading pocket has been installed below the 750 level. The capacity of the measuring pocket can be changed from 60 to 80 cubic feet by the removal of a baffle plate.

Figure 3 shows the standard station layout at *C* shaft; except for the sump, this is typical of all the levels.

Development Levels

Five levels have been established at each shaft. with the lowest, or 750, serving as the present main haulage. At *B* shaft, and at *A* shaft for the first development, level intervals were spaced for the most suitable approach to development of the orebodies, as indicated by diamond drilling. At *C* shaft, the levels conform with those at *B* shaft, since it was felt that a connection on two or more levels might be required eventually, and there was no apparent need for a special level interval in the *ASD* zone.

For each level, the course of primary development is decided strictly on its merits. The exact locations of the headings are determined by their ability for definition diamond drilling of the orebodies, and for the eventual mining of the ore. With the flat plunge, and irregular shapes, much of the development has to be done in barren ground below the ore. Prior information is obtained by diamond drilling, from the levels above or from alternate headings on the level itself.



Loading from a mucking-machine draw-point.

Drifts and Cross-Cuts

Drifts and cross-cuts are 8 ft. by 8 ft. in cross-section. They are driven by a three-man crew operating a 2-boom hydraulic jumbo, usually on a 2- or 3-shift basis. Rock drills are $3\frac{1}{2}$-inch drifters using one-inch quarter-octagon drill rods and detachable steel bits. A mechanical loader is used to muck out the rounds. During a shift, the crew mucks out the round blasted by the previous shift, advances track, air and water pipes, drills off the round, and blasts. The average advance per round is 7 feet but advances up to 10 feet per round have been obtained.

Miscellaneous headings are driven by a miner and helper, using a $3\frac{1}{2}$-inch drifter mounted on a bar and arm. They advance air and water pipes, drill off, and blast the round during one shift. The round is mucked out and the track advanced by a two-man mechanical loader crew on the opposite shift.

Sub-drifts, which vary in size from 5 ft. by 7 ft. to 7 ft. by 8 ft. in cross-section, are usually driven by a two-man crew using air-leg drills and tungsten-carbide-tipped drill steel. A scraper-hoist is used by a two-man crew on the opposite shift, to remove the broken rock.

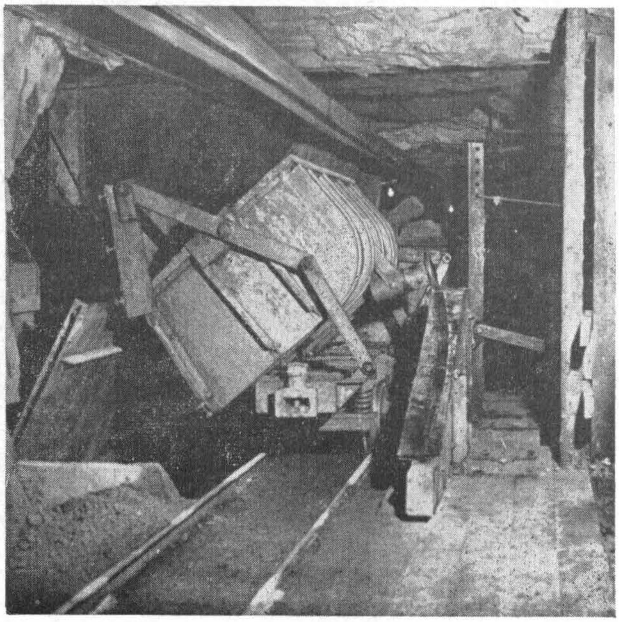
Raises

Raises are from 5 ft. by 5 ft. to 6 ft. by 12 ft. in cross-section, and are driven by a two-man crew on a single-shift basis. Three-inch stopers and detachable steel bits are used. Advance per round ranges from 5 feet to 8 feet.

Ore and Waste Passes

At *A* and *C* shafts, the ore and waste passes are driven at 50 degrees, generally knuckled back at a point about half way to the level above, and are 6 ft. by 10 ft. in cross-section. Grizzlies of 85-pound rail are installed in both passes on each level. A branch by-pass raise is driven from 35 feet below the level to a short cross-cut adjacent

Loading from a steel and concrete chute on the 750 main haulage level.



Dumping arrangement at the ore by-pass on the 750 main haulage level at *C* shaft.

to the grizzly. The raise is continued to the next level above from this cross-cut. To control the flow of muck, ball-and-chain gates, operated by a hand winch, are installed in the by-passes at each level.

At *B* shaft, the layout is similar, except that no by-pass raises have been provided. Openings, with steel plate guards, have been cut in the grizzlies to allow the muck from the level above to flow freely through to the lower levels. Ball-and-chain control gates are installed in the raises immediately above the openings.

Fill Raises

At *B* shaft, fill is supplied to a sub-drift and to the 100 level through one compartment of a 6 ft. by 12 ft. timbered raise. The other compartment is used for ventilation and as an escape manway. Warm air, supplied to the ventilation compartment during the cold weather, warms the adjacent fill compartment and helps prevent the gravel fill from freezing and consolidating.

The main *B* area fill raise system is about 800 feet north of the shaft, and extends from the 575 level to surface. The raises are 6 ft. by 10 ft. in cross-section and are inclined at 50 degrees. Fill is drawn off on the 250, 425, and 575 levels through steel and concrete loading chutes equipped with air-operated ball-and-chain gates. Dumps are provided at the by-passes on the levels to dispose of development waste into the fill system.

At *C* shaft, it is planned to use the main waste pass for fill distribution. It has been so laid out that it can be tapped by short raises from each level to draw off waste, or gravel fill from surface.

Fill will be provided at *A* shaft through a raise from the 200 level to surface, similar to the combined ventilation and fill raise at *B* shaft. This will supply fill for stopes above the 325 level.

Mining

Attitude of the Ore and Selection of Mining Methods

The orebodies occur in zones, or envelopes, of chlorite and sericite schist. These schist zones vary in attitude from nearly vertical to sub-horizontal and in places assume an arch-like, or a trough-like, outline. Regardless of the attitude of the zones themselves the schistosity planes dip steeply, with minor variations at from 60 to 80 degrees to the west.

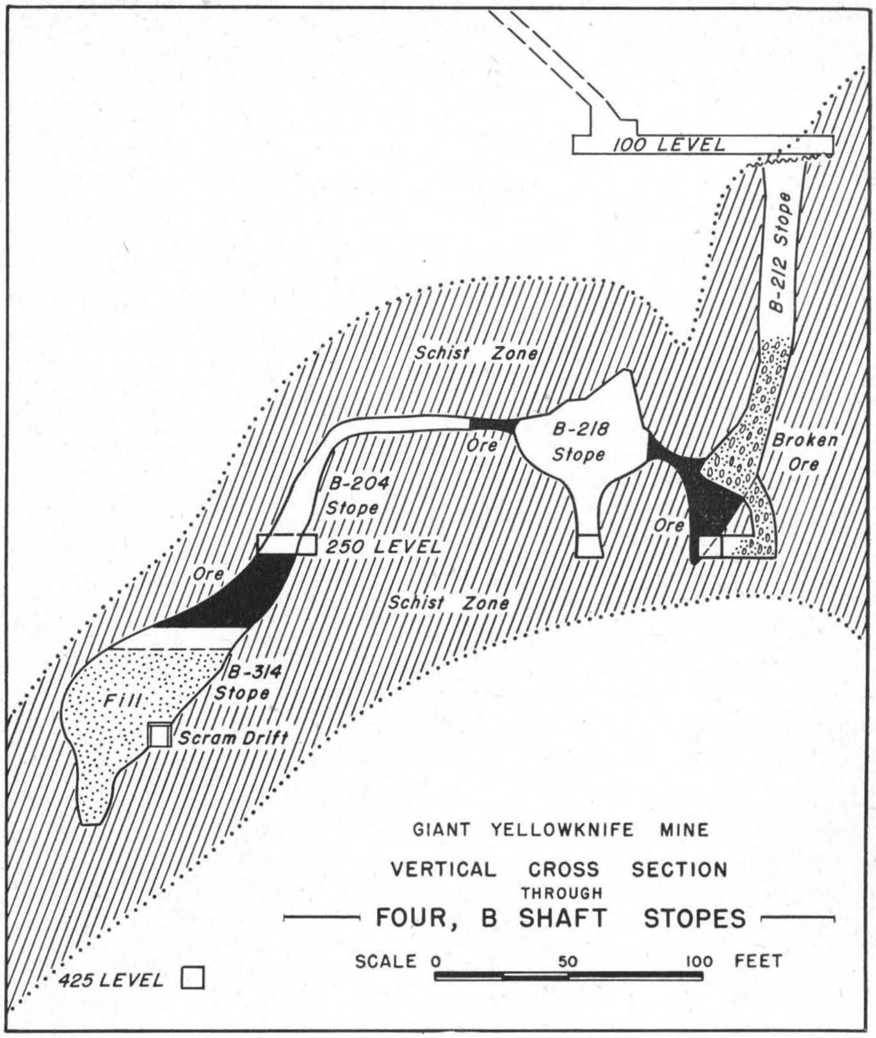


Figure 4.

In the *B* and *C* Shaft areas, where, so far, all the mining has been done, the orebodies may be visualized in a broad way as long sausage-like masses, plunging to the north at low angles, which average about 25 degrees. In detail they are exceedingly complex, and the ore outlines may roughly conform with the schistosity, or cut across it at any angle. For a further description of the orebodies and the schist zones, and the reasons for their being, reference should be made to the paper by Brown and Dadson (pp. 59-76). In general, the ore can be classified into 'high-angle' and 'low-angle' types. A given block of stoping ground may consist of one or both of these.

Although local weaknesses may be caused by 'slips', both walls and ore are surprisingly strong, considering the degree of schisting, and the selection of a mining method for any particular stoping area is largely governed by the shape and size of the ore block.

Cut-and-fill, shrinkage, and open stoping are the three mining methods presently employed. From the start of production until October, 1950, all production came from either shrinkage or open stopes. At that time the first cut-and-fill stope was brought into production and others have followed in the more complex and low-angle orebodies. It is estimated that in the near future approximately 80 per cent of the ore produced will be obtained from cut-and-fill or open stopes and 20 per cent from shrinkage stopes.

Figure 4 illustrates the application of the three mining methods to ore of various attitudes, and also shows the outline of the enclosing schist. In *B*-314 stope, the ore dipped steeply, below, and for 18 feet above, the elevation of the sub-level drift. This portion was mined by shrinkage. Between this and the 250 level, the average dip of the ore is too flat for shrinking. The broken ore was drawn off on the 425 level, the stope filled, and the upper portion is presently being mined by cut-and-fill. The flat dipping *B*-204 and *B*-218 stopes, of limited vertical extent, were open stoped. Shrinkage was used for the steep-dipping *B*-212 stope.

Since drifts and cross-cuts provide few clues to the attitude of the ore, practically all information, prior to stope layout, is obtained from definition diamond drilling. This includes data for estimates of tonnage and grade, as well as for determination of the ore boundaries and mining limits. Generally, the drilling is done on cross-sections spaced at 50-foot intervals and closed in to 25 feet where the need is apparent.

In some cases, the shapes of the orebodies cannot be accurately determined from diamond drilling. Simple high-angle ore may suddenly develop into the low-angle type, extending flatly over an area which may be measured in thousands of square feet, and more holes seem only to compound confusion. Conversely, an orebody which has been interpreted, from diamond drill holes, as a single low-angle shear, may eventually be found to be composed of steep lenses of ore. An example of the latter is to be seen in the *B*-215 stope, where a low-angle orebody above the 250 level extended northward for 450 feet from *B* shaft. By joining up definition drill intersections, a continuous orebody was indicated, 5 to 40 feet in thickness, with a dip of 20 degrees to the west and an areal extent of 450 by 175 feet. A regular open stope was laid out and started, but after a short period of mining it became apparent that a large part of the ore occurred in steeply dipping *en échelon* lenses, individually of considerable length but of limited vertical extent. Highly selective mining, combining open and cut-and-fill stoping, with frequent changes of layout, has now been adopted. This has resulted in an ore grade much higher than the original drill estimates and, surprisingly, no decrease in the tonnage. Including pillars, this stope now extends over an area of more than 70,000 square feet.

Each new block of ore presents a specific problem of extraction, and the amount of drilling performed, before starting the stope, is governed by the information needed to decide which mining method is applicable.

Pillars

Due to the nature of the distribution of orebodies it has not been found necessary to establish an overall pillar system for the mine. In most stopes sufficient ground support is obtained by leaving natural pillars of waste or of low-grade ore. The orebodies extending to surface are covered by permanently frozen overburden and the extraction of surface pillars presents a special problem.

Standard Stoping Equipment and Materials

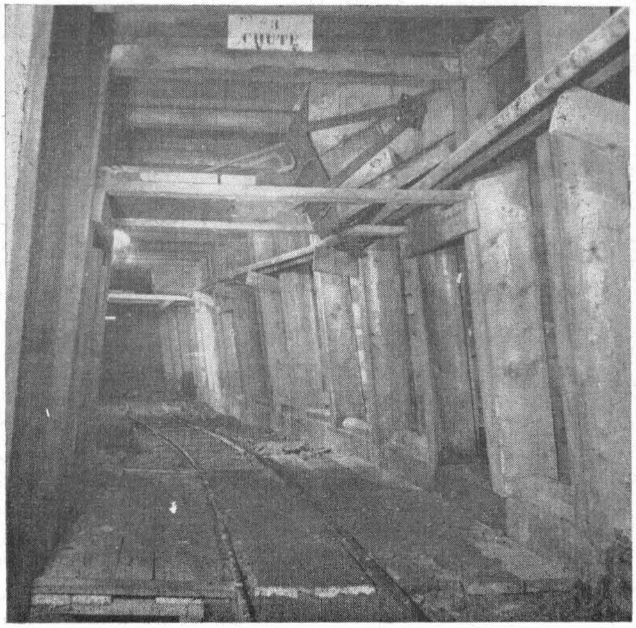
Light weight air-leg rock drills and tungsten-carbide-tipped drill rods up to 16 feet in length are used for drilling in all stopes after stope preparation has been completed. Blasting is done with 70 per cent Driftite and millisecond delay caps.

Rock bolts of various lengths are used, as required, to support the stope walls in areas of weakness. With the exception of rock bolts and the occasional stull or crib, very little timber is required for support.

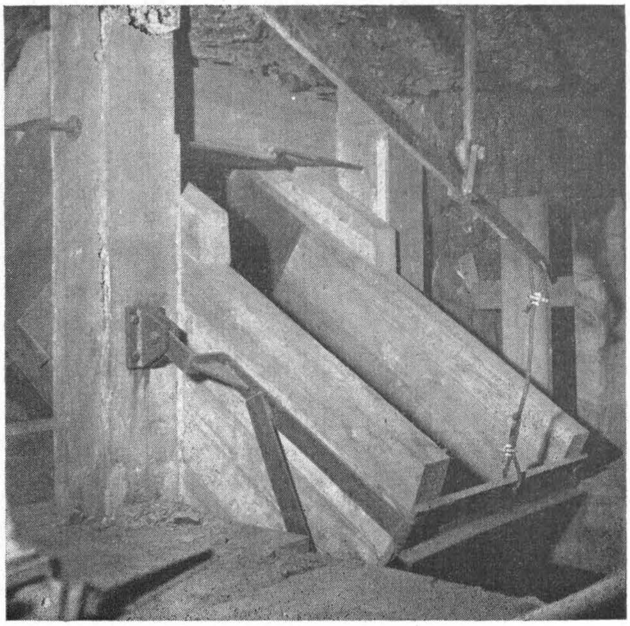
Scraping equipment used in stopes or scram drifts consists of 10 h.p. air or electric, and 20 or 30 h.p. electric, scraper-hoists equipped with 36- or 42-inch hoe-type or folding scrapers to suit the size of the hoists. The distribution of the units is governed by the size of, and conditions in, the stopes. Sealed beam or compressed-air-driven lights are used for lighting stopes and scram drifts.

Cut-and-Fill Stoping

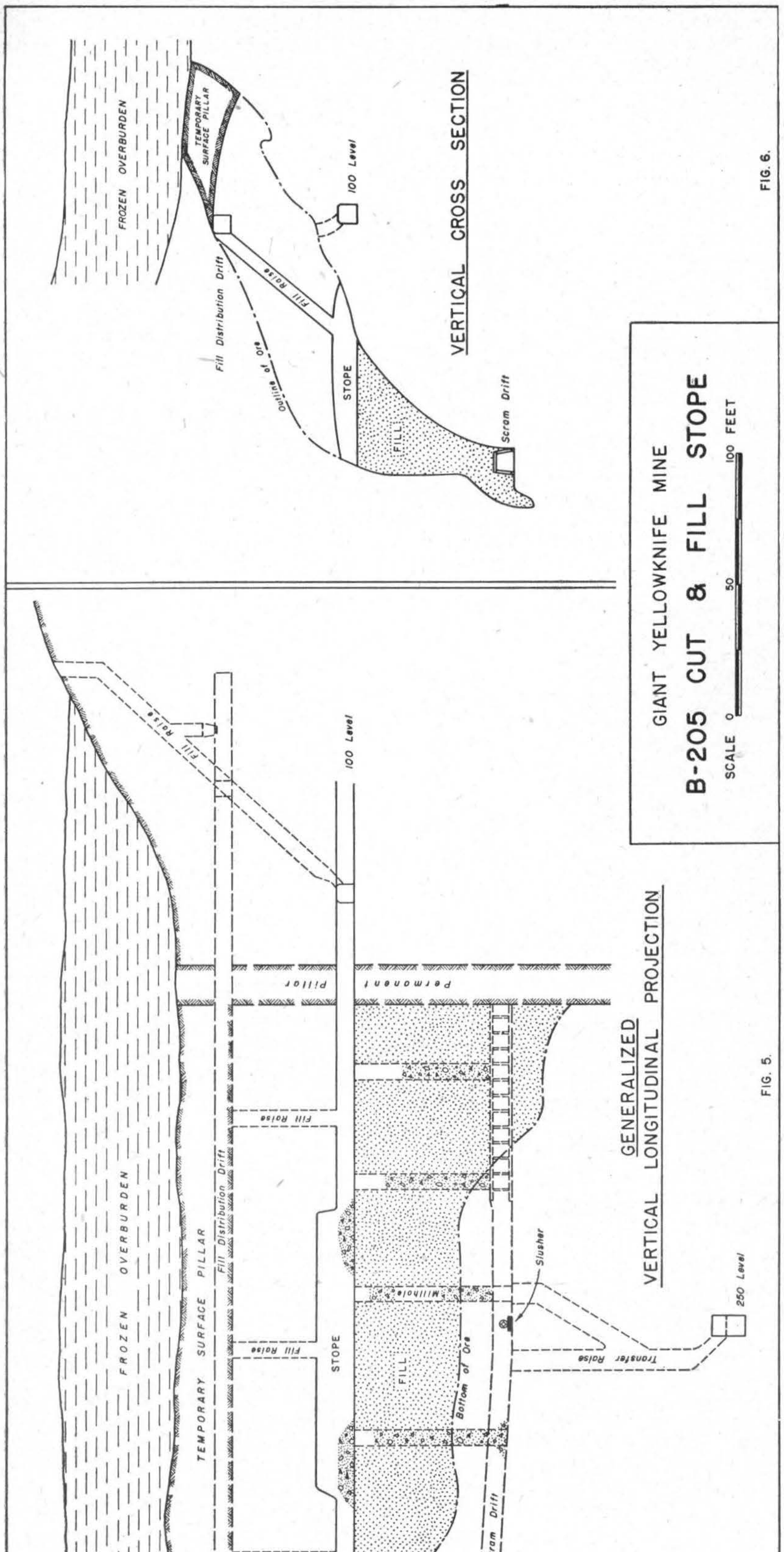
Fill raises, 5 ft. by 7 ft. in cross-section, and spaced at 100- to 150-foot centres, are driven through the ore at 50 degrees. Millholes are spaced at 40- to 75-foot intervals, and manways as required. Where the bottom of the ore is a short distance above the development drift, box-hole raises are driven 8 feet into the ore, connected by sub-drifts, and the ore is slashed out to the assay limits. Ore on the level is slashed out to the assay limits at drift elevation and the backs taken down to a height of 18 feet above track. In relatively narrow sections, standard drift sets are placed at 4- or 6-foot centres and the caps lagged with round timber. In wider sections, timber drifts are installed. Sets are placed at 4- or 6-foot centres, the caps lagged with round timber, and the posts with 6-inch split lagging.



Timber drift and chutes under a cut-and-fill stope,



Cut-and-fill chute.



Figures 5 and 6.

Breasts are carried 8 ft. high and stope backs are arched where necessary. Grade marks for both back and fill elevations are set by the surveyors. Millisecond delay caps are used following the second lift above the timber. Millholes and manways are separate and each measures 6 ft. by 6 ft. inside the timber. Grizzlies over the millholes consist of 85-pound rail spaced to provide 12-inch openings.

Figures 5 and 6 show a generalized vertical longitudinal projection, and a vertical cross-section, through *B*-205 cut-and-fill stope. Broken ore from the lower portion of this stope flows from the millholes into a scram drift and is scraped into a 6 ft. by 10 ft. transfer raise to a draw-point located on the 250 level. Ore from the upper part of the stope will be drawn off through box-hole chutes located on the 100 level footwall drift. Fill for the lower portion of the stope was trammed from the fill raise on the 100 level, and it is distributed to the upper part through a sub-drift in the surface pillar. An air locomotive equipped with a 42-in. by 72-in. air receiver is used to haul the fill in the sub-drift.

A considerable tonnage of high-grade ore is contained in the surface pillar of this stope, and plans have been made for its recovery. It is overlain by permanently frozen layers of sand and clay, gravel, peat, and muskeg, with an average depth of 40 feet. In this particular area, the permafrost extends from surface to below the 250 level. Before starting mining of the pillar, all unnecessary openings into the stope will be sealed with reinforced concrete bulkheads. The mining will be done during the winter when the air in the stope can be kept at near freezing temperature. It is believed that, with the aid of a relatively small amount of timber, the frozen overburden can be supported long enough for the removal of the ore. In view of the possible eventual thawing, the remaining openings will be sealed off, when all of the broken ore has been drawn, to isolate the stope completely from the other mine workings.

Converted Stopes

Before fill became available, certain large stopes in the *B Shaft* area were started by shrinkage, though flattening of the dip, or branching shoots, in the upper portions indicated that conversion to cut-and-fill would be necessary.

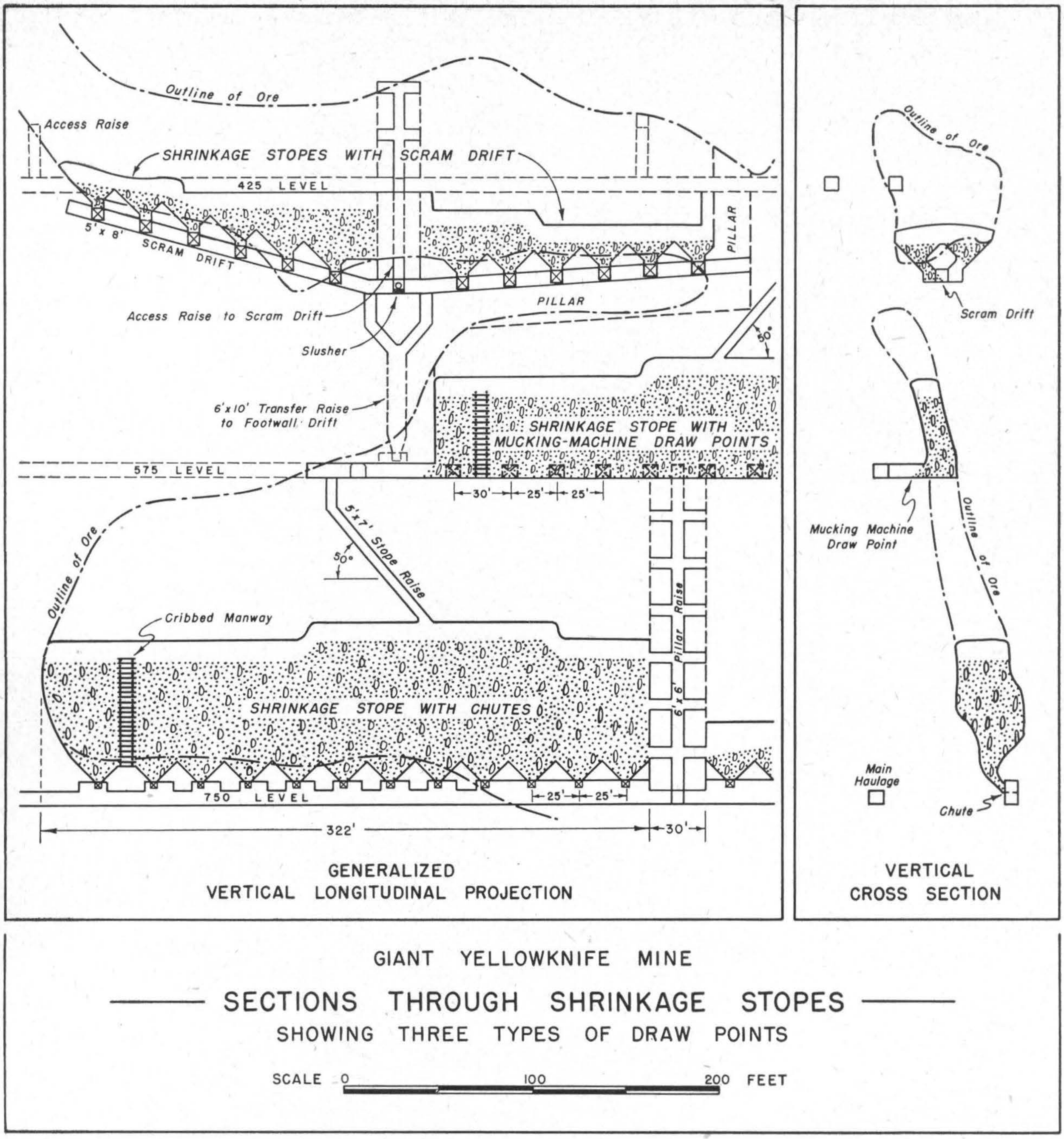


Figure 7.

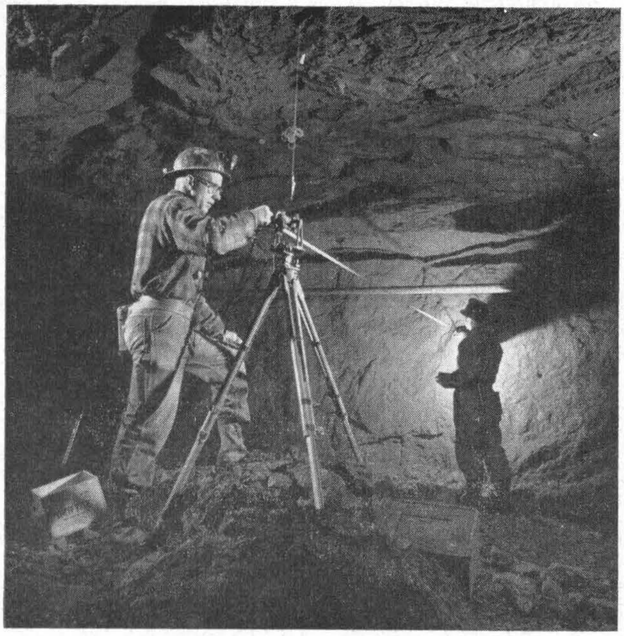
When the limit of shrinkage was reached, fill raises were driven before the ore was drawn from the stopes. After drawing off the broken ore, the openings were filled to within 8 feet of the backs. Six-foot by six-foot box-hole raises were driven, at 50 degrees from a footwall drift, to break into the stopes at a distance of 12 feet below the backs. This was done to eliminate the dangers associated with the practice of raising millholes in the wide, empty stopes. With the resumption of mining by cut-and-fill, timbered millholes are being carried up through the fill from these raises, and the broken ore is drawn off through chutes on the level below.

Shrinkage Stoping

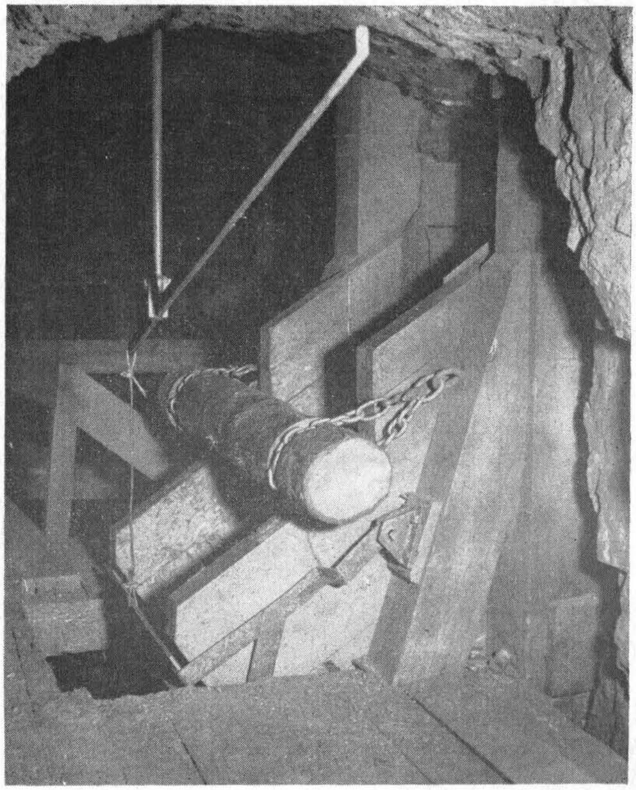
Figure 7 shows a generalized vertical longitudinal projection and a vertical cross-section through four shrinkage stopes in the *C Shaft* area. It illustrates three different types of draw-points and the general stoping practices employed.

The broken ore from the stope immediately above the 750 level is drawn through boxhole chutes. After the development drift had been driven, the ore in the back was taken down for a height of 14 feet above rail. Where the ore did not reach the level but was known to exist above, sections of the back were taken down at each chute raise location for a length of 15 feet. Boxhole raises, spaced at 25-foot centres, were driven for three rounds, after which the chutes and loading platforms were installed. The box-holes were then coned to connect with adjacent boxholes.

Access to the stope is provided by a 6 ft. by 6 ft. raise in the 30-foot pillar at the north end of the stope, with short sub-drift connections to the stope at 25-foot vertical intervals. In addition, a cribbed manway, measuring 6 ft. by 6 ft. inside the timbers, is carried up through the broken ore at the south end. A 5 ft. by 7 ft. raise inclined at 50 degrees allows access from the level above.



Surveying a cut-and-fill stope.



Shrinkage chute.

These raises provide adequate natural ventilation for the stope.

The second stope is provided with mucking-machine draw-points on the 575 level. A drift was driven through the ore the full length of the stope and slashed to the assay limits. A footwall drift was driven with its centre line at a minimum distance of 25 feet from the footwall of the ore, and mucking-machine cross-cuts, 8 ft. by 8 ft. in cross-section, were driven at 25-foot centres from the footwall drift to the stope. Where a cribbed manway was required, adjacent mucking-machine cross-cuts were spaced at 30-foot centres and a manway cross-cut, 7 ft. by 7 ft. in cross-section, was driven midway between them. Access is provided by a cribbed manway at each end of the stope and a central inclined stope raise to the 425 level.

The broken ore from the two upper stopes is discharged into a 5 ft. by 8 ft. scram drift and scraped through grizzlies over fingers to a central 6 ft. by 10 ft. transfer raise to a loading chute on the 575 level footwall haulage drift. Draw-points are located at 25-foot centres on the same side of the scram drift. Where others are required they are staggered between the draw-points on the opposite side of the drift. Adjacent draw-points are connected by coning. A 6 ft. by 6 ft. pillar raise provides access to the scram drift. Access to the stope is gained from the 425 level, as illustrated.

Footwall drifts on the levels serve a double purpose. In addition to their utility for mining, they provide diamond drill locations to outline the ore between the levels.

Shrinkage stopes are mined by taking horizontal slices 8 to 10 feet in height. Breasts are started at the stope raise and carried north and south to pillars or to the ore limits. If no stope raise is provided, slots are cut at the rib pillars and the breasts advanced along the length of the stope.

When the mining is completed, the broken ore is drawn from the stopes. As the ore is pulled down, the footwall is cleaned off and stulls with head-blocks, or rock bolts with 6 in. by 8 in. timber placed over the bolts and tightened against the walls, are placed where necessary to support loose ground.

Open Stoping

Open stoping follows no fixed procedure. This method is used to mine out flat-dipping or complex ore shoots, provided that the height of exposed backs can be maintained within reasonable limits.

Stoping may start by the slashing of ore from the development drift and loading with a mechanical loader. As stoping progresses, a scraper hoist is used to transfer the broken ore to the loader, or to a ramp loading directly into the cars. Sufficient broken ore is left at the face to provide a working platform while mining.

Where the bottom of the ore shoot occurs above the level, raises from box-hole chutes or mucking-machine draw-points may be driven into the ore, access raises provided, and the broken ore scraped through these raises to the draw-points.

Stope Control

At Giant, where milling costs are relatively high, unusual efforts are made to limit dilution. In many orebodies, cheaper non-selective mining methods could be used, but the resulting dilution would increase the milling cost per ounce and more than offset the saving in mining costs. Selective mining of the irregular orebodies pays off, but it requires a close check on the mining limits through co-operation between the geological and mining departments. Clean mining involves boundary control and internal control, the latter because of 'horses' of waste within the stope. So far, very little marginal-grade ore has been encountered, and nearly always the material is either ore or waste. With practice, the two can be distinguished visually.

The geologists visit each working place daily and map the geology of a stope from the time stope preparation is started until the mining is completed. They chalk the ore boundaries exposed in the stope, and indicate the depth to which the ore might be expected to extend into the walls, as determined by test holes and other data. Working maps, consisting of 20-scale plans and vertical cross-sections at 25- or 50-foot intervals, are carried by the geologists. All pertinent geological, diamond drill, test hole, and assay information is shown on these maps. In addition, the outline of the stope on the previous slice and the predicted outline of the slice being mined is shown. Copies of the stope plans are posted in the shift bosses' office and periodically brought up to date. Weekly meetings are held by the mining, geological, and engineering departments at which all current mining problems are discussed.

Arsenic Disposal Stopes

The arsenic trioxide by-product of the roasters has to be collected and stored, in order to minimize the risk of contamination of surface or of underground workings. At the present 700 tons rate, about 10 tons of As_2O_3 are collected daily by the Cottrell plant. Storage space is provided at Giant in special stopes which are excavated in greenstone, at some distance from the hanging-wall of the ore zones, beneath a heavily overburdened area adjacent to the outcrop on which the Cottrell plant is built. Here, permafrost extends to over 270 feet below surface, and prevents any movement of underground waters.

To date, two disposal stopes have been mined out above the 250 level by shrinkage. The first has already been filled. The dimensions of the second are 114 feet in length, 30 feet in width, and 170 feet in height. The back is arched to form an elongated dome shape, and the surface pillar is 100 feet thick.

The broken waste from the stope was drawn off through four mucking-machine draw-points, driven from a dead-end cross-cut on the *B Shaft* 250 level. The draw-points were joined by coning. Two cribbed manways provided access to the stope, and a compressed-air-driven fan assisted ventilation. Loading with a mechanical loader permitted the handling of large pieces of waste and reduced secondary breaking to a minimum. The broken waste was trammed for fill.

After completion of stoping, a 5 ft. by 7 ft. raise was driven at 50 degrees to the outcrop near the Cottrell, the thawed ground near surface sealed by grouting, and a concrete collar poured.

A timber bulkhead was installed in the raise at its lower end and stulls were placed on line at 6-foot centres along the floor of the raise to support necessary pipes and ladders. Two 4-inch 'Carlon' pipes are used, one to discharge arsenic trioxide, the other to blow cold air into the stope in winter to compensate for the heat added to the stope by the warm arsenic trioxide and accompanying air. The electric fan, used for blowing the cold air, is located in a small house over the top of the raise. A 15-inch metallic ventilation pipe leading into a bag house provides an air escapeway to surface. In addition there is a 12 in. by 15 in. closed wooden chute through which are passed coarse pieces of arsenic trioxide cleaned from the rabble arms of the flat-hearth roaster. Pipes and chute extend through the bulkhead into the stope and all were made airtight to prevent contamination of the raise. A sealed door in the bulkhead permits inspection, and measurement of the arsenic trioxide level in the stope. Electric lights have been installed in the raise to facilitate inspection.

A waterproof, reinforced concrete bulkhead placed in the 250 level cross-cut isolates the stope from the other underground workings. This bulkhead is designed to withstand a hydrostatic pressure proportional to its depth below surface.

Fill

Gravel fill is trucked a distance of three miles from the pits to the mine, and dumped through grizzlies into the fill raises. Working conditions are severe in the pits during the coldest winter months and blasting is sometimes required in order to load gravel. Due to permafrost and the shallow depth of the stopes to which the fill is being supplied, some difficulty has been experienced in preventing the fill from freezing in the raises. Consideration is being given to the use of de-slimed mill tailing for fill material in certain parts of the mine.

Haulage

Standard track gauge is 24 inches and grade is 0.5 per cent favouring the load. The track on the 750 haulage level from *C* to *B* shaft is 40-pound rail and either 30- or 20-pound rail is used elsewhere in the mine. Curves are of 30-, 50-, or 70-foot radius.

Ore and surplus waste on all levels above the 750 and from stopes or development headings on the 750 level are hauled to the passes in 27½ or 38½ cu. ft. side-dump cars by 1½- or 3½-ton battery locomotives and dumped through a grizzly.

Ore and waste from the *A* and *B Shaft* workings are drawn from steel and concrete chutes at the bottom of the passes on the 750 level. These chutes are equipped with air-operated ball-and-chain gates. The ore is hauled to *C* shaft in 60 cu. ft. Granby-type cars and dumped into the ore by-pass, which is equipped with a retractable ramp and hinged steel cover. The ramp and dump cover are air-operated and controlled simultaneously by a 4-way valve. Waste is dumped through a grizzly into the waste pass. A 3-ton trolley locomotive is used to haul the ore and waste from *B* shaft, and a 3½-ton battery locomotive for haulage from *A* to *C* shaft.

Ventilation

Air is forced down the ventilation compartment of the combined ventilation and fill raise at *B* shaft (previously mentioned under *Fill Passes*) by a 28-inch fan, located on surface. It delivers 12,000 cubic feet of air per minute. The fan is installed in a separate building in conjunction with a thermostatically controlled oil burning unit heater. The air is discharged through a duct to the ventilation raise. During the winter months, warm air is supplied to the workings.

Regulating doors are installed in the shaft cross-cuts on all levels. During the winter, these are adjusted so that *B* shaft has a slight down-draft. The air flows from the *B* Shaft workings through the *C* and *A* Shaft workings, causing an up-draft in both shafts. At *A* shaft, a compressed-air-driven fan on the 750 level, and regulating doors in the shaft cross-cuts on all levels, adjust the supply of air to this area.

A 15 h.p. electric fan is available for shaft sinking or for ventilating long development headings. Isolated headings of lesser extent are ventilated by smaller compressed-air-driven fans through 15-inch ventilation pipe.

Electric Power

The mine is serviced by 550-volt, 3-phase, 60-cycle electric power, transferred to a switch room on each level through armoured cables. This provides for the trolley locomotive, electric scraper-hoists, charging of batteries, ventilation, pumping, and lighting. A 30-kilowatt, 250-volt d.c.

generator is located midway between *B* and *C* shafts on the 750 level to supply power for the trolley locomotive. Transformers are provided on each level to supply 110-volt power for lighting and for the block signal system on the 750 main haulage level.

Mine Organization

The mining staff is divided into two departments, Mining and Engineering, responsible to the Mine Superintendent.

Mining

This department consists of a mine captain, an assistant mine captain, and eight shift bosses. In addition, a timber boss supervises timbering throughout the mine. An electrical foreman, responsible to the Chief Electrician, is in charge of electrical work. A mine mechanical foreman, responsible to the Plant Engineer, is in charge of underground mechanical equipment.

All mining is done on a two-shift basis, from 8:00 a.m. to 4:00 p.m. on day shift and from 7:00 p.m. to 3:00 a.m. on night shift. The underground crew consists of about 200 men.

Engineering

The Engineering Department is under the direction of the Chief Engineer. The Chief Surveyor, Contract Engineer, and Layout Engineer are directly responsible to him. The individual detailed layouts required for mining the irregular orebodies are produced under his supervision. Development and production schedules are drawn up on a monthly, quarterly, yearly, and long-range basis. This department also assists in the preparation of estimates for the ordering of mine upplies.

Surveying

All underground and surface surveying is done by four surveyors under the direction of the Chief Surveyor. They handle all engineering maps, plotting, etc., calculate the amount of ore broken for the month, and supply other information required for the calculation of contract earnings.

Contracts

The calculation of contract earnings is in charge of a Contract Engineer, assisted by a mine clerk. This sub-department also handles research on the testing of new equipment, and on the performance obtained on various underground operations. The information is used to increase efficiency and adjust contract earnings.

All mining, and as much timbering as possible, is contracted to the miners. Drifts, cross-cuts, and raises are paid per foot of advance, including drilling, blasting, mucking, and installing track and pipes. Price variations are made only on the size of the heading, the method of driving, and the type of rock. In stopes, payment is made on the number of tons broken, ore and fill slushed, etc. Additional payments are made for raising millholes, manways, installing rock bolts, and miscellaneous timbering jobs. Prices vary according to the types and widths of the stopes.

Geology

The geological staff consists of four men under the direction of the Chief Geologist. Though forming a separate department, a large part of their work is done in close co-operation with the mining staff. In the matter of stope control, mining and geology are inseparable.

The more specific responsibilities of the geologists are connected with exploration and development. These include geological mapping, planning of primary development headings, layout and execution of exploratory and definition drill holes, interpretation of drill results, and the building-up of a picture of the ore block prior to stope layout. The geologists also direct the samplers, and make all tonnage and grade calculations. Research on the problems of ore deposition, and long-range planning for future development, is an important part of their work.

Sampling

Sampling is done by three samplers who take daily chip samples of freshly broken faces in development headings and stopes. Experience has shown that areal chip samples give a more reliable determination of ore grades than channel samples. Car samples are taken by the tramming crews and collected by the samplers. Assays are marked on working plans, and current and cumulative sample averages are kept for each working place. A check is made each month of the average of car samples against the mill feed. No corrective factor has yet been determined, but, over a period of years, by cutting high assays down to five ounces, the average grade from car samples checks very closely with the mill feed.

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