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NOTES ON COPPER MOUNTAIN GEOLOGY

As requested, I have prepared a few notes setting forth the current ideas about the geology of the Copper Mountain mine and their application in directing present exploration and development. These notes are the result of a visit to the mine from July 8 - 12 inclusive, 1950. The information is based in part on personal observations underground and on the surface, and in part on discussions with Mr. Keith Fahrni, Chief Geologist at the mine and his staff, to all of whom I am deeply indebted for much of the information in these notes.

The ore occurs in volcanics, that include flows, tuffs, and breccia and are adjacent to gabbro. The volcanics belong to the "Wolf Creek Series", Triassic in age, and the gabbro is part of the "Copper Mountain Stock", Jura-Cretaceous in age.

The orebodies comprise two rows of stout, vertical pods that parallel the contact of the gabbro. One row, comprising the "Contact Orebodies" is immediately adjacent to gabbro, and the other row, comprising the "Outlying Orebodies", is from 200 feet to and farther into the volcanics. The amount of ore mined and in reserves is about equally distributed between these two spatial types of orebodies.

Features that are thought to be most directly related to the orebodies include:

(1) - the contact between the volcanics and the gabbro.

(2) - the Main Fault.

(3) - the set of ore-bearing fractures.

(4) - pre-ore feldspar porphyry dykes.

(5) - one or more zones of laminated tuffs.

(1) The "Contact Orebodies" are in the volcanics immediately adjacent to the gabbro contact. A small amount of mineralization has been found in the gabbro near the contact, but no orebodies. At the mine the gabbro contact strikes northwesterly and in general has a vertical dip; northwesterly from the mine the contact swings westerly and probably retains its vertical dip; southeasterly from the mine, the contact swings

southerly, but the dip reverses into the stock and in places, as indicated by diamond drilling, may be as flat as 40 degrees. The "over-hang" theory of Dr. Dolmage and Keith Fahrni is based on this reversal in dip of the gabbro contact southeasterly from the mine. According to this theory the orebodies at the mine were formed beneath an overhang that has since been eroded away. Although recent drilling about a mile southeasterly from the mine has indicated a reverse dip to the contact and consequently an overhang, and some scattered copper values have been found, no substantial amounts of ore were found. However, the theory of an overhang as a contributory factor in localization of ore along those parts of the contact where a reversed dip occurs, has not been disproved.

(2) The "Outlying Orebodies" are clustered along the Main Fault. This fault, including its branches, strikes northwesterly and at the mine is parallel to the gabbro contact. However, northwesterly and southeasterly the contact swings,

respectively westerly and southerly, and along these sections the Main Fault is not parallel to the contact. As there is also a tendency for the "Outlying Orebodies" to diverge from the "Contact Orebodies" northwesterly and southeasterly from the mine, there may be a definite correlation between the Main Fault and the occurrence of the "Outlying Orebodies". Although current exploration is being confined to ground near the gabbro contact, it is hoped, at a later date, to explore ground along the trend of the Main Fault, away from the gabbro contact.

(3) The orebodies are blocks of ground that are cut by a prominent set of vertical, northeasterly striking, closely spaced fractures, referred to as the "ore fractures". These fractures, and the intervening rock have been mineralized with bornite and chalcopyrite to give the orebodies. The best mineralization occurs where these northeasterly striking "ore fractures" cut other favourable structures.

(4) Considerable mineralization has been found in an easterly striking set of feldspar porphyry dykes where these dykes intersect the Main Fault; similar dykes with a different strike do not contain ore. These dykes are not to be confused

with the many light-coloured felsite dykes that definitely cut the orebodies and are unmineralized.

(5) Although the Wolf Creek Volcanics are principally "greenstones" all somewhat similar in appearance, careful observation and detailed mapping has made it possible to recognize four lithologic types, in order of superposition, coarse fragmentals, bedded or laminated tuffs, flows, and cherty rocks. The zones of fragmentals, tuffs and flows are each about 400 feet thick, the zone of cherty rocks considerably less. Orebodies have been found in each of these zones where favourable structures intersect, but much more ore has been found where the favourable structures intersect the zone of laminated tuffs. Extended mapping has led Mr. Fahrni to believe that there is a cyclical repetition of these zones and that therefore either underlying or overlying zones of the favourable tuff may occur that could be intersected by favourable structures. An overlying tuff zone occurs about 1,000 feet above the principal main zone and some ore has been found in it, and it is thought that

there may be a zone of tuffs underlying the main mine-tuffs. In this connection, it is a striking feature of the orebodies that they bottom along a line that slopes southeasterly in the direction of the dip of the volcanics and that this line also coincides with the bottom of the favourable tuff-zone. This bottoming of the ore occurs despite the fact that other favourable structural features, such as the gabbro contact and the north-easterly striking ore fractures, continue downwards. However, based on the cyclical theory of Mr. Fahrni, it is to be expected that other favourable tuff-zones would be found below the present orebodies and that ore would be found where these zones were intersected by favourable structures. It is planned to test this thought by deep drilling.

In addition to the search for "deep-ore" below the Contact Orebodies, attention is also being directed toward ore possibilities at some distance from gabbro contact. Such ore comprises the "Outlying Orebodies" and in these, ore has been found as far as 1100 feet from the contact. One of the widest post-ore felsite dykes, the "A" dyke, which with its branches has a thickness of about 200 feet, is found at about 1100' feet from the contact. Because of temporary mining problems imposed by this thick, vertical dyke, no attempt has yet been made to find ore beyond the dyke. However, it is planned to explore the ground beyond this dyke as soon as the "38" block of ore, just inside this dyke, has been developed and suitable drilling stations have been established.

At the present time mining and milling methods at Granby are designed for about 5,000 tons of ore per day. No. 6 level has been made the main haulage level. All ore from above 6 level is loaded directly into ore cars, but ore below this level must be hoisted to the level by means of an internal shaft. As the capacity of this shaft is 2,500 tons per day, production from 6 level or above it must be kept up to 2,500 tons to keep the total tonnage at about 5,000 tons. If new ore were found below 6 level it would be necessary to increase the hoisting capacity of the shaft. This requirement makes it necessary to find as much ore as possible above 6 level either from local extensions of the known contact and outlying orebodies above 6 or from new orebodies at some distance from the contact.

The mining of any new ore found above 6 level also presents a problem. The method of mining found most suitable to the Copper Mountain orebodies results in the subsidence of ground above the orebodies as they are mined. Chronologically, in any one section of the mine, the orebodies are mined and ground caved on a retreat system, gradually working towards the Main or No. 1 Shaft. This means that direct access to new ore found by drilling beyond the caved areas has been lost and that new and probably circuitous levels have to be driven in order to reach the new ore. Some of the new Outlying Orebodies, such as the 38 block found beyond caved ground, have been proven valuable enough to go out after, even when direct access from the shaft has been lost, and it is planned to drive the new levels necessary to reach this ore.

VOIGT'S CAMP

This "camp" is on Wolf Creek about 8,000 feet northeasterly from Copper Mountain and comprises a small group of claims owned and prospected by Mr. Emil Voigt from 1889 until his death in 1927, and now owned by Granby. The mineral deposit consists of an easterly trending shear zone that cuts the Wolf Creek volcanics and the Voigt gabbro, belonging to a stock separate from the Copper Mountain stock and lying northeasterly from it. This shear has been mineralized with abundant hematite, and moderate amounts of chalcopyrite and pyrite. Extensive trenching has been done and several short adits have been driven on the property and some ore found. During the past year (1949-50) Granby cleaned out an adit on the east side of the road and did some diamond drilling from it. Although drilling indicated that the ore found in crosscuts from this adit extended a considerable distance below the level of the adit, further exploration in the adit and elsewhere in Voigt's camp has been suspended for the present.

CURRENT SURFACE EXPLORATION

This summer (1950), it is planned to drill several of the anomalies found by a geophysical survey made in 1937. This survey was made along a section of the gabbro contact that extends from the southeastern limit of the mine workings to the southeastern tip of the Copper Mountain stock.

The programme of detailed surface mapping, using a stadia-plane table method with transit control, began a year ago, is being continued this year. The company hopes to map in detail the northeastern contact of the gabbro. To date they have nearly completed the area covering the mine workings and an area that extends along Wild Horse Gulch for about 6,000 feet westerly from "Voigt's Camp".

J.S. Stevenson
August, 1950.

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Copper Mountain
Analysis of Tonnage from Co's sheet

Tonnage and grade

Since reopening in 1937 the tonnage has risen from ~~1-1/4~~ 1.22 million in 1938 to ~~1-3/4~~ 1.76 million in 1941. It dropped slightly from the peak in 1942 and dropped to about 1.37~~0,000~~ million in 1943. The total tonnage milled, from the start of large scale milling in 1925, is about 13,720,000, the recovered copper 21,75 pounds per ton which calculates back to an average head of 1.33% copper (at 82% net recovery)

The highest mill head attained, in 1938, was 1.48%, with the exception of 1926 when the grade was 1.65%. The grade averaged about 1.4% until 1941 when it dropped to 1.285%. It was 1.14% in 1942 and about 1.0% in 1943. The grade of the 1943 tonnage has been calculated from Company figures (statements of cost of production of copper, cost of freight on ore, etc.)

The falling off in grade, starting in 1941, appears to have been the result of excessive dilution and not of mining lower grade ore except to an insignificant degree. The dilution, always a problem in the vicinity of the mine dikes, was aggravated by the method of mining which resulted in actual overbreak during development stages and pervasive shattering of the walls due to the setting off of huge blasts.

The company shipped concentrates to Japan from 1937 until 1941. In 1942 the output was bought by Wartime Metals Corporation at a bonus price of 16.7¢ per pound of copper and continued until December, 1943. Costs in 1943 amounted to 15.7¢ per pound of copper produced, and with cancellation of the contract the company, with an operating cost of $1.73 per ton, was faced with the necessity for reducing costs or raising grade or both in order to operate at the U.S. price of 11.7¢ per pound of copper.

At the time of visiting the mine the company intended to maintain the grade at 1.1% and to lower operating costs if possiblee to $1.11 per ton.

It is impossible to estimate what the costs will be, as only the company officials are in a position to do that. Their figure of $1.11 is not a proven figure but only an estimate. The new method of stoping will undoubtedly lower the mining cost, but how much remains to be seen. dMr. Baillie stated that he hoped to lower mining and milling costs to 40 odd cents per ton each, and also to prune down the general and overhead expenses. It is not impossible that the operating costs will be lowered to $1.25 per ton and maintained at that figure.

The following figures on reserves and the estimates of grade are from the company's ore reserve sheets, dated January 1st, 1944.

Net total ore developed throughout the life of the mine amounts to 23.61 million tons which is derived from a calculated developed tonnage of 26.97 million tons less an estimated 3.36 million tons non-recoverable.

This 23.61 million tons of net ore developed at a grade of

1.54% has been depleted by 12.13 million tons at a grade of 1.46%. This last is an artificial figure, calculated in terms of depletion of primary and undiluted reserves. This is obvious because the grade is higher than the average grade throughout the life of the mine and the tonnage balances the figures of netatotal ore developed in the case of mined out stopes, in spite of the fact that dilution in these has obviously occurred. In fact the contact ore-body above 6 level has, from a sheet showing broken and drawn tonnages, been overdrawn by 300,000 tons and is not yet empty. This depletion figure of 12.13 million tons is a calculated reduction of undiluted tonnage and is not tonnage drawn from the mine, which is 1.56 million tons larger.

The net total ore developed less depletion gives total available ore reserves of 11.58 million tons at a grade of 1.63% which is a semi-artificial figure representing available mineable and undiluted tonnage and represents actually a balance of copper content, i.e., mineable copper stocks less depletion to date.

The total available ore reserves of 11.48 million tons cannot be mined as such but must suffer dilution. The Company sheet shows a dilution of 51% (5.86 million tons) with material at a grade of 0.35%

to produce an estimated total extraction of 17.34 million tons at a grade of 1.20 per cent.

Further analysis of the tonnage figures, up to and including the total available ore reserves of 11.48 million tons, is impossible on account of the fact that they are based on multitudinous engineering data and upon years of experience beyond the capacity of an outsider to digest in a short time. The figure largely represents unbroken tons. The amount of dilution of course governs the total tonnage that will be drawn in obtaining the equivalent of 11.48 million tons at a grade of 1.63% and the amount of dilution, affecting the grade substantially as it does, is a matter for argument as well as concern.

In the figures for the previous year the company estimated a dilution of 36% with a grade of 0.35% which converted a reserve of 12.45 million tons at 1.61% to an estimated total extraction of 16.91 million tons at a grade of 1.28%. The inference is that the present figure of 51% dilution is based on the fact that the operation during the last two or three years has suffered from excessive dilution. An estimated increase in dilution from 36% to 51% for the remaining life of the mine, does not seem justified in view of the fact that the newly developed method of mining is particularly designed to reduce dilution.

It is possible to analyze the matter of dilution in a general way from the Company's figures. The results are of course only very general approximations. The total depletion of 12.13 million tons obviously does not represent drawn tonnage but a depletion of ore-bodies as outlined by exploratory work. A depletion of 13% increases this figure to the total of drawn tons (13.72 million tons), which dilution at the accepted Company figure of 0135% gives a grade of 1.33%, the average figure for the life of the mine. The fact that almost one half of the depletion figure (5.89 million tons) is derived from stopes carried on the books as exhausted and the fact that only about 1 million tons are carried on the books as existing broken in stopes, makes the figure of 13% dilution one that might be expected for the remaining life of the mine providing conditions remain the same as in the average of the past.

One factor, however, tends to increase this figure as applied to the available reserve figure (11.48 million tons at 1.63%).

This, it has been pointed out, is a semi-artificial figure to balance the books and not an actual measurement of remaining ore. The grade is 0.07 higher than the total developed ore in spite of the fact that a large part of the contact ore-body, of better than average grade, has been mined out. It is perhaps reasonable to believe that the copper content represented is contained in more tons at lower grade than is given, which in effect is the equivalent of some dilution in actual mining.

A higher percentage of ore in the past has come from the gabbro contact zone where the volume of mine dikes is small compared to what will be mined in the future. In other words, future mining in dike-infested zones is susceptible to more dilution than in the past.

Another factor that might increase dilution above the average of past history is that of caving. A large amount of ground has caved to surface and further settlement is to be expected. Whatever the mining method employed some dilution from this cause will take place - not much in the case of greenstone which is apt to fail in large blocks but perhaps an appreciable amount in the case of the mine dikes which may become shattered due to caving forces alone.

On the other hand the new method of stoping with diamond drilling is designed to combat dilution and should in some measure be successful. Rigid control of drilling and quick drawing should minimize dilution within each stope.

It is only the writer's belief, but a strong belief nevertheless, that the effective dilution of the 11.48 million tons of available ore reserves will be of the order of 30% over a period of years and not 51% as indicated. If the grade of dilutant material is 0.35% as calculated in all of the company figures the estimated total extraction will be not 17.34 million tons at 1.20% but 14.92 million tons at 1.33%.

If this figure is approximately correct there is in the mine a total available tonnage sufficient to last nearly ten years at a grade the equivalent of that mined in the past.

At the outset however, there is not this grade of ore obtainable and the reserve of broken ore is shown to be of a grade of only 1.09%. The company broken ore sheet shows 915,000 tons, which is an artificial figure produced by the subtraction of a calculated overdraw of 428,800 tons in three stopes from broken ore in other stopes - actually then the figure is 1,344,000 tons, of which 369,000 is not immediately available, or an available broken tonnage of 974,000 tons. While this is being drawn work will be directed to catching up on development which has lagged and more particularly to convert the mining method to the newly developed system of breaking by diamond-drilling.

The actual cost of operation during this period of transition cannot well be estimated, but it is a fair guess that the mine should be operating on a satisfactory basis by midsummer of 1944.

The foregoing figures are by no means accurate but are intended to indicate that in all probability there exists about 10 year's ore at a production rate of 4,500 tons per day with a grade between 1.3 and 1.35% copper. This grade is about the same as the average for the 13 million tons already mined. It is impossible to analyze costs on so short and imperfect an acquaintance with the mine, but on the basis of the Company's analyses it would appear that with this grade and tonnage the operation can probably carry on at a copper price of 10¢ per pound.

Nothing has been said concerning gold and silver values. These, over the life of the mine, average about 30¢ per ton recovered, or 33¢ at current prices. At a production rate of 4,500 tons per day (1.7 million tons per year) this amounts to about $500,000 dollars yearly, at least adequate to meet depletion and depreciation of about $300,000.

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Copper Mountain

Mining Methods

The company started to mine by spiral stoping in the large ore-bodies and shrinkage stoping in the smaller ones, in addition to glory holes. The spiral stoping became modified to fit the ground and, in 1941, apart from a few shrinkage stopes mining was by large blasts which broke as much as 500,000 tons at one time. During the last two years a modification, termed "long-slope" mining was adopted. This involved the systematic removal of 20% of the ground by a series of dog-leg raises, drilling the remaining ground closely with percussion drills and blasting large blocks at once.

This method of mining resulted in an undue amount of dilution, partly due to the shattering of the walls (and particularly of the relatively weak mine dikes) and partly also due to the fact that control of development was difficult. In the latter respect some of the dog-leg raises would get into waste and have to remain in waste until ~~it~~ they could be brought back into ore again - this it is true could be circumvented in part but the fact remains that it needs extremely close supervision and a highly competent mine crew for efficiency.

Recently a totally different method of mining has been adopted, one that is capable of rigid control and one that produces an absolute theoretical minimum of overbreaking and shattering of walls. This is a sort of modified shrinkage stoping by blasting horizontal slices with diamond-drill holes. The holes are drilled in radiating patterns from raises, which are 100 to 150 feet apart. The slices are 10 feet thick.

The holes are 6 feet apart at the boundaries of the ore-body and are loaded for varying lengths from the bottom to allow for an even powder distribution in the slice. The muck is drawn to about 8 feet below and the entire slice is blasted at once and, in dropping, is fragmented.

The holes are 1-3/16 inch diameter, drilled with a plug bit, and, are loaded with 1-inch powder.

The drilling is done on contract and the work to date shows clean breaking to prescribed limits, ~~far~~ far closer and easier control, and better fragmentation than in the large blasts of the former method. The outlines of an ore body are contoured by the geological and engineering staff and the exact position and length of each hole is calculated and drawn up in the office, and the drill crew of two men working at a prescribed setup merely follow a clearly understandable chart.

Results to date show an average daily footage drilled of 80 feet of hole, and a consumption of about 0.15 pounds of powder per ton of ore broken while still in the experimental stage.

Drilling is at present from available raises driven for another type of mining. These are dog-leg, 50-degree raises which are not best suited to this type of mining. The best raise is of small enough cross section that all drilling for a slice can be done from a single setup and so located that holes on the footwall side of the ore-body can be drilled somewhat tangentially so as to provide a side swiping affect; holes drilled radially will result in vertical or inward receding walls for ends and hanging wall. Vertical or steeply inclined raises driven near the footwall of the steeply dipping ore bodies would improve the breaking performance but ~~will~~ would initially cost more than the 50-degree ~~dog-leg~~ raises previously driven.

The over all effect of this method will apparently be to lower the cost of primary breaking, decrease dilution and, by better fragmentation, to lower the cost of secondary breaking. Average costs cannot yet be assigned but initially the method is a success.

Shrinkage stoping will continue to be carried out in certain of the smaller ore-bodies.

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Report on

Copper Mountain Mine

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1943.

The following summary account of Copper Mountain mine is the report on a seven day visit to the mine from February 9 to February 15, 1944 by M. S. Hedley and S. S. Holland acting under instructions to gain a familiarity with the mine and an understanding of the geological setting.

Prints of the following maps were obtained from the company and are attached:

Claim map

Contoured surface map

Maps of Levels Nos. 1 to 8 on a scale of 1" = 100'

Two Longitudinal sections through the contact ore zone

Two Plans showing layout and loading data for a Diamond Drill Blast.

Introduction:

The Copper Mountain mine is on the summit and western slope of Copper Mountain, 12 miles south of Princeton. It is developed for a length of 6,000 feet, a width as great as 1,000 feet and a depth of 1,400 feet. Mine-run ore is crushed at the portal of No. 6, the main haulage adit level and is hauled by railroad to the mill at Allenby, 8 miles distant. All ore mined above No. 6 level is transferred down to it by a system of raises and ore mined from the lower levels, Nos. 7 and 8, is hoisted in a vertical shaft.

After many years of surface exploration and some underground development, during which time a mill was built, the property was acquired by the Granby Consolidated Mining Smelting & Power Company Limited in 1926. The mill was modified and increased to a capacity of about 2,500 tons daily, and the company operated continuously until 1930 when the price of copper fell below a profitable level.

Operations were resumed in 1937 when the company further expanded the mill to an ultimate capacity of about 4,500 tons per day, and supplied their own power in a steam generating plant using fuel from their own coal mine. All concentrates were shipped under contract to Japan.

In 1942 the concentrates were sold through Wartime Metals Corporation at a bonus price and this contract was maintained until December, 1943, when the contract was cancelled.

The mine is a low grade one, operating on about 1.4 per cent copper for a number of years, but the grade fell far below that figure during the past three years. Gold and silver values are low. Reserves have been maintained to about ten year's supply during the last seven years, but little exploratory work was done in 1943. The underground crew has fallen off with the manpower shortage from about 400 to 120 men.

Geology:

The following geological summary pre supposes a prior reading of Dolmage's "Geology of Copper Mountain", Memoir 171 of the Geological Survey of Canada.

The surface geology, in spite of widespread overburden, was accurately mapped by Dolmage from outcrops and from many old prospect trenches in the vicinity of the mineralized area that were open for inspection at the time of his work.

The Copper Mountain ore-bodies are in belt of volcanic rocks lying along the northeast contact of a differentiated gabbro stock. A second stock lies several thousand feet to the northeast. In the belt of volcanics between the Copper Mountain and Voigt stocks are a series of intrusive bodies mapped by Dolmage as the Lost Horse diorite. A swarm of ramifying, post-mineral felsite porphyry and granophyre dykes cut the Copper Mountain stock, volcanics, and ore-bodies in the neighborhood of the Copper Mountain mine. Pegmatite stringers and dykes cut the margin of the gabbro and the adjacent volcanics.

The volcanic rocks as seen in the Copper Mountain workings consist of fine grained dark tuffs, some of which show bedding in a few places, as well as volcanic rocks of other types. A band of coarse volcanic breccia is exposed in crosscuts on 6 level and also on 8 level. Dark grey equigranular or porphyritic rocks in the volcanics may possibly be dykes or sills of pre-mineral age. The general strike of the volcanic rocks is northwest, parallel to the northeast contact of the Copper Mountain stock, and observed dips are to the southwest, towards the gabbro contact. Although the volcanic rocks are considerably altered and have few easily recognizable features it might be possible by detailed mine mapping to work out folded structures within them. That the volcanics are drag-folded is indicated by the surface pattern of some beds mapped by Dolmage, but not published in his Memoir 171.

The Copper Mountain stock is well described by Dolmage. Its northeastern contact is important because of the ore-bodies lying along it. The marginal phase of the stock is a massive dark grey equigranular rock containing biotite and described by Dolmage as a syeno-gabbro. For several hundred feet from the volcanic contact the gabbro is foliated parallel to the contact. For four or five thousand feet in the vicinity of the mine workings the northeastern gabbro contact is almost straight, with only minor irregularities and a slight convexity to the northeast, while at depth the contact is almost vertical within the range of the mine workings, about 1,400 feet.

The Voigt stock lies a mile to the northeast of the Copper Mountain stock. It is too far away to appear in any of the mine workings or diamond drill cores.

Dolmage maps large and small areas of Lost Horse intrusives lying to the north of the mine workings, northward from the Princess May ore-bodies. However, in crosscuts to the east on 6 level, 500 feet and more from the gabbro contact, there are exposures of altered volcanic rocks whose alteration is attributed to Lost Horse intrusives. This particular area of volcanic rock is important because of the outlying ore-bodies within it. There is however no exposure of actual Lost Horse intrusive rock seen in the mine workings and geological information is notably deficient as to the position and contact of the Lost Horse intrusive. It is not known whether it exists either as a continuous intrusive body or as a series of isolated intrusions to the northeast and east of the gabbro stock. The Lost Horse intrusives appear important, for most outlying ore-bodies lie in its alteration zone, yet nowhere is the actual intrusive encountered underground.

Pegmatite forms the core of the Copper Mountain stock. In addition narrow pegmatite stringers and dykes cut the gabbro margin of the stock as well as the adjacent volcanics. The pegmatite dykes in the volcanics are intruded along fractures parallel to the ore-fractures. The pegmatite stringers and dykes may contain some bornite, may be accompanied by a narrow selvedge of biotite alteration in the invaded volcanics, or by a bleach alteration of both gabbro and volcanics. Formerly it was thought at the mine that the pegmatites brought in the ore, but this view has been abandoned largely because there is no spatial relationship between the occurrence of ore and the abundance of pegmatites.

The Mine dykes are light coloured felsite porphyry and granophyre dykes which cut the gabbro, volcanics and ore-bodies. They are unmineralized and shatter readily so that in the mining operation they add a considerable amount of dilution.

Rock Alteration:

Throughout the mine workings the rocks are altered in varying degrees and in a variety of ways. The most pronounced alteration seen underground is a biotitization of the volcanic rocks marginal to the gabbro stock. This alteration is a contact metamorphic effect related to the gabbro intrusion, but it appears to be variable, as though original differences in rock composition might have influenced its intensity. The biotite alteration zone extends for 400 feet or more eastward from the gabbro contact. It is not known whether biotitization of volcanics in the eastern zone of Lost Horse alteration is related to the gabbro or not.

The other pronounced alteration of the volcanic rocks is in the vicinity of the outlying ore-bodies; it lies several hundred feet east of the gabbro contact but approaches the gabbro in the zone of the Princess May ore-bodies. It is characterized by the formation of a dense chert-like rock with a pale olive green cast, presumably from the development of small augite grains. It is accompanied in places by a blotchy development of pinkish coloured feldspar, and by a coarsening of the rock texture. This alteration is more intense to the east, away from the gabbro, hence it is presumably related to the Lost Horse intrusives even though none of those rocks are seen underground. The distribution of the Lost Horse alteration zone is not shown on the mine geological plans.

The pegmatite stringers are accompanied by a bleaching of either the gabbro or volcanics, presumably from the introduction into them of feldspar. There appears to be no difference between the bleaching accompanying pegmatite, and that accompanying ore deposition; many ore fractures in the contact zone are bounded by a bleached zone. Occasional hairline cracks of epidote are seen in the gabbro.

The two rock alterations, biotitization and Lost Horse type, are particularly prominent. To what extent their development is influenced by original rock compositions or fracturing is not known. The biotitization preceded the deposition of ore but it is not known whether the Lost Horse alteration preceded or accompanied the ore. Of the two, however, the Lost Horse appears the more important because of its relation to the outlying ore-bodies.

Ore-bodies and mineralization:

The Copper Mountain ore-bodies are in zones of intense rock alteration and in a zone where the Mine dykes are most abundant. Of the numerous ore-bodies of the Copper Mountain mine the most important during early stages of development were those which are in biotitized volcanics along the northeastern contact of the gabbro stock. They extend along the stock for about 3,000 feet, outcrop at the surface at two points and bottom approximately at 8 level, having a vertical range of about 1,400 feet. The various other ore-bodies referred to as outlying ore-bodies are in the altered volcanic rocks to the east of the Contact ore-bodies. The Princess May ore-bodies, although close to the gabbro contact, lie a thousand feet or so northwest of the Contact ore-body and differ materially from it; actually they are more like the outlying ore-bodies in mineralization and rock alteration. There are no Mine dykes in the barren zone between the north end of the Contact ore-bodies and the Princess May.

The mineralization of the Contact and outlying ore-bodies differ in that the Contact is predominantly bornite with small amounts of chalcopyrite while the outlying ore-bodies are largely chalcopyrite with a small amount of bornite and some pyrite. It is remarkable to note that there is no quartz as veinlets or gangue in any part of the mine workings.

The ore mineralization is controlled by the ore-fractures which strike more or less at right angles to the gabbro contact and dip northwest from 65 to 80 degrees. No individual fracture extends for any great distance, but both the margin of the gabbro and the adjoining volcanics are fractured; there is no ore in the gabbro. The ore minerals are deposited as thin films along the ore-fractures and in high grade contact ore there is considerable disseminated bornite between the fractures. The disseminated bornite appears to be in biotitized volcanics but not in the bleached rock which bounds some ore-fractures and some pegmatites. Although the dominant direction of ore-fracturing is northeast there is a very much weaker conjugate direction almost east and west which is mineralized as well.

In the mine the ore-bodies in general have assay boundaries except against the sharply defined post-mineral Mine dykes and in general against the gabbro. The tenor of the ore depends on the closeness of the spacing of the mineralized ore-fractures and, in the Contact ore-bodies, on the amount of disseminated copper minerals between them. The outlying ore-bodies have a ragged, fringed outline because of the control exercised by the ore-fractures. On the mine plans the outline is an arbitrary boundary that only in a very general way shows the shape of the ore-body. Actually both ore-fractures and ore mineralization extend beyond the limits of the mapped ore-bodies. Even within the ore-bodies there are fairly continuous bands of poorly mineralized or barren volcanics that must be mined with the ore.

Longitudinal cross sections through the outlying ore-bodies show them dipping steeply to the northwest, reflecting the dip of the ore-fractures. Transverse cross sections through them indicate a general tendency for them to plunge steeply to the southwest towards the gabbro contact, but they do not quite reach it.

Practically all of the ore-bodies are bottomed fairly sharply between 6 and 8 levels. This bottomming of the ore above the 8 level constitutes a major geological problem, the proper interpretation of which has an important bearing on future exploration.

The dominant bornite mineralization of the Contact ore-body in the biotitized volcanics along the gabbro contact stands out in sharp contrast to the chalcopyrite mineralization of the outlying ore-bodies in the Lost Horse type of alteration. The significance of this difference is not known but it is suggestive of different origins for the two types of mineralization. At the present stage there is nothing to suggest or prove that the ore came from either the gabbro stock or the Lost Horse intrusives. But some explanation of the mineralogical difference is necessary. Should more importance be attributed to the Lost Horse intrusives than to the gabbro then a considerably greater area is available for further exploration.

Structure:

The regional trend of the volcanic rocks is northwest and the dips are generally to the southwest. However during the course of his surface mapping Dolmage mapped the outcrop of a coarse grained non fragmental ~~breccia~~ bed whose zig-zag pattern strongly suggests that there are plunging drag-folds within the volcanic belt. Bedding observed in the mine dips towards the gabbro contact and the position of a coarse volcanic breccia on 8 and 6 levels indicates that all the ore-bodies developed so far lie in a wedge of volcanic rocks bounded on the west by the more or less vertical gabbro contact and on the east by the southwesterly-dipping coarse breccia bed.

Four generally east-west faults cut the rocks and ore-bodies. They may be accompanied by a wide shattered zone but do not have a displacement of more than 25 feet. Throughout the mine there are numerous other slips and fractures having little or no displacement but some of which are occupied by calcite stringers. The post-ore Mine dykes occupy an extensive fracture pattern whose significance is not definitely known.

The ore-fractures are discontinuous cracks occurring in swarms and having a northeast strike and a steep northwest dip.

Dolmage stresses the fact that the biotitized volcanics are foliated parallel to the gabbro contact and that the ore-fractures are at right angles to the foliation. In conversation he suggested that the ore-fractures are complementary tension openings at right angles to the direction of elongation. However on 6 level southeast a pegmatite stringer was seen occupying an ore-fracture but having subsidiary branches at an angle suggesting tensional openings at an angle to a shear direction. Moreover examination of many ore specimens reveals that beside the predominant ore-fracturing direction there is a subsidiary mineralized fracture direction whose pattern reflects the same set of conditions. There is a suggestion therefore that the ore-fractures are shear plane directions that have subordinate tension fractures associated with them. This is no more than a suggestion but it is believed that a thorough structural analysis could prove the nature of the fracture pattern and might be of value in exploration.

The importance of the ore-fractures is apparent but the distribution of the fracturing and the relationship to possible folded structures in the volcanics, or to different rock types or zones of rock alteration, is not known. The whole course of future ore exploration hinges on the correct interpretation of these relations and the projection of the correct hypothesis into hitherto unexplored areas.

The bottomming of the ore-bodies above 8 level evidently is due to the lack of ore-fractures at that depth, probably because of the appearance of a rock type that did not fracture suitably. The appearance of coarse breccia close to the gabbro contact suggests a wedging against the gabbro. The rocks on 8 level appear different from those above; they are softer and are strongly sheared parallel to the gabbro contact. This shearing does not appear on 6 level and is difficult to explain.

Hypothetical Considerations:

Formerly it was considered at the mine that the pegmatites were the feeders of the mineralization. This idea has been abandoned since later development work has shown no spatial relationship between the number of pegmatites and the occurrence of ore-bodies.

The mineralogical differences between the Contact and outlying ore-bodies suggest that the two mineralizations are from separate sources. The present emphasis is to place more importance on the Lost Horse intrusives. This is particularly significant now that most of the Contact ore-body is mined and much of the developed ore reserve is in the outlying ore-bodies apparently related to the Lost Horse intrusive. However the actual source or sources of the mineralizing solutions is of less importance than the knowledge of the factors that have resulted in the distribution of the ore-fractures. An important point is to determine whether the Lost Horse type of alteration conditioned the volcanic rocks so that they subsequently were brittle enough to fracture or whether the rock alteration accompanied the mineralization along pre-existing ore-fractures.

The explanation of the spatial distribution of the ore-fractures is exceedingly important. It would require extremely detailed geological mapping of the mine workings, the careful plotting of minute differences between various types of volcanic rocks, the plotting of intensities of rock alteration of the various kinds, and the plotting of the density of ore-fractures and whether they are mineralized or not. This together with further information regarding the size, position and contacts of Lost Horse intrusives to the east of the mine workings are necessary to explain the distribution of the ore-bodies. At present it is possible to say that the ore-bodies are known only in a wedge of volcanic rocks bounded on the west by the gabbro contact and on the east by a coarse volcanic breccia.

Cannon, the mine geologist, suggests that the 32, 34 and 37 ore-bodies on 6 level lie in an embayment in the Lost Horse alteration zone. Moreover the Princess May ore-bodies, which lie in a zone of Lost Horse alteration is close to the gabbro contact only because the Lost Horse intrusive is nearby. There seems no doubt but that there is ore associated with the Lost Horse alteration zone. The real deficiency is the lack of knowledge regarding its position and extent.

Although the Mine dykes are younger than the ore it is significant that the greatest number of them is in the zone of ore-bodies. Dolmage maps none either north or south of the mine but to the northeast at Voigt's Camp there is a second swarm of them. The implication of this may be that the Mine dykes occupy a fracture zone that primarily served as a channel way for the introduction of mineralizing solutions into the fractured volcanic rocks.

Geological Problems:

The most important geological problem at Copper Mountain has to do with the localization of the ore-bodies. It is true that they are primarily controlled by ore-fractures but further information is required in order to explain the distribution of the ore-fracture system. Subordinately a study of the rock alteration is required mainly for the information that might be applicable to the fundamental question and to assess if possible the relative importance of the gabbro stock and Lost Horse intrusives.

The ore-control appears to be largely a structural problem whose explanation can only be obtained from a most detailed examination of the mine workings in conjunction with a surface study in special sections.

Substitute for p. 13 / written by A.S. Baillie

The main value of such work would be to the Copper Mountain mine, for the success of future ore exploration largely depends on it, but valuable information should result that might be of direct benefit to the development of the Voigt camp deposits.

Mining Methods:

Mining started in early years of operation with spiral stopes in large ore-bodies and shrinkage stopes in small ore-bodies, as well as glory holes. The spiral stopes were modified to suit conditions and during the last two or three years a system of "long slope" mining was employed. This consisted of systematically removing 20 per cent of the ground in an ore-body by a number of 50-degree raises, closely drilling the intervening ribs with percussion drills and blasting a whole block at one time.

The large blasts which have broken as much as 500,000 tons at once, resulted in more dilution than was anticipated. However, the falling off in grade during the past three years has been partly attributable to dilution and partly to the lower tenor of the ore blocks mined. The Company's development policy established in 1937-38 was determined after giving full consideration to the two important factors of (1) maximum recovery of ore, and (2) mining by the most economical methods. This policy necessitated the removal of the ore in proper sequence to insure maximum ore recovery regardless of the fact that certain blocks involved were of lower tenor. Some dilution, particularly from the mine dykes and weak walls, is inevitable regardless of the type of mining but the large blasts did produce boulders which further tended to increase the dilution due to channels between boulders permitting the seeping through of finer low grade material which by-passed the ore.

The mining of large ore-bodies close to the surface has resulted in much subsidence. There is one caved area about 800 by 3,000 feet, largely in the area of former glory holes, and this will increase somewhat as mining continues. In most sections the caving is on a 70-degree slope down to the workings below, but in some instances it is as low as 50 degrees.

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The large blasts, which have broken as much as 500,000 tons at once, resulted in more dilution than the operation could stand, and the falling off in grade during the past three years is attributable to dilution and not to a lower tenor of the ore. Some dilution, particularly from the Mine Dykes, is unavoidable but the large blasts produced too much shattering of the ground.

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Recently an entirely new method of stoping has been evolved. It is in course of trial at present but there is no apparent reason why it should not prove satisfactory for most of the ore-bodies which are too large to be mined economically by standard shrinkage stoping.

This new method is a modified form of shrinkage stoping in horizontal slices drilled off with a diamond drill. Holes are drilled in a radiating pattern from conveniently located raises 100 to 150 feet apart within an ore-body. The holes are 1-3/16 inch in diameter, drilled with plug bits, and are loaded with 1-inch powder to a uniform areal density, and the entire series of holes is blasted at once. Each slice is 10 feet thick.

In practice the outlines of the ore-body are predetermined and the pattern of holes is laid out in the office, a print of which is furnished to the contract drill crew. The drillers then follow instructions implicitly as to the length of each hole and the divergence between holes, ideally drilling a complete horizontal ring from one setup in each raise. The holes are loaded to a calculated powder density and the horizontal slice is sheared at one blast, dropping about 8 feet to the muck below to insure fragmentation.

It has been found to date that rigid control of the outlines of the stope is possible; there is little shattering of the walls, due to the fact that the holes are spaced about 6 feet apart along the stope walls at each 10-foot interval; and fragmentation is better than that obtained by the former methods of large blasts. The costs appear already to be substantially lower and a reduction in secondary breaking cost is an added advantage. By rapid drawing of completed stopes it is believed that dilution will be kept to a minimum.

Ore-bodies:

As already stated the ore-bodies are for the most part copper-bearing zones with assay boundaries. Their outlines are established as a compromise between grade and cost of mining. There are about 45 named ore-bodies in the mine, some of which are distinct only because various factors favour their separate mining. In detail the outlines are ragged and ribs of low-grade material exist in or extend through them, but for purposes of mining the limits are set more or less arbitrarily to take in maximum tonnage at a profitable grade.

The Mine Dykes have a great influence on mining since they cut through some ore-bodies and form boundaries of others. Being barren and structurably weak the laying out and operation of stopes is, as far as possible designed to limit the chances of dilution by dyke material. In a few instances attempts have been made to mine the dykes separately but not with complete success; in many parts of the mine ore and dyke are mined together at a reduced grade within a single ore-body when it is evident that the dyke rock can not be left as a pillar.

In point of view of total tonnage the largest ore-body is that known as the "contact", with about 6 million tons. Next are the "36" with 3.36 million tons and the "A14" with 2.4 million tons. The smallest ore-body contains about 50,000 tons.

The contact ore-body is now mined out above 6 level and only a relatively small proportion remains, partly in unmined ground below 6 level and partly as sill pillars. It was the first body to be fully explored, being for its size the highest in grade, and for some years it was considered to constitute most of the total mine tonnage rather than about one quarter as now known.

The contact ore-body follows the gabbro contact for about 1,000 feet, has a width ranging from 10 to 150 feet and a total depth of 1,400 feet. It reached the surface only at one point and only one small section persists for a short distance below 8 level. Other bodies exist on the gabbro contact which, genetically, may be considered as part of the same ore-body, with a total developed tonnage 29 per cent of the known mine.

The other ore-bodies lie within the volcanics as far as 800 feet from the gabbro. Not all reach the surface and none persist downwards as far as 7 level. The greatest single cross section, in 36 ore-body, is 150 by 500 feet. Several of the ore-bodies are in reality parts of a single large ore zone separated by dyke rock.

In the early stages of mining most of the ore came from the Contact and related ore-bodies, where there is very little dyke rock and the percentage of dilution was small. At the same time the ore was relatively high in grade. In more recent years more and more ore has come from the outlying ore-bodies within, for the most part, two major ore zones. The grade is satisfactory in these ore-bodies but there are many dykes. This is the zone in which there is greatest dilution, to a point where, unless better mining methods are used, the operation is imperilled at current copper prices.

Production:

Since the start of large scale milling operations in 1925 the mine has produced approximately 3,720,000 tons at a grade of 21.75 pounds of recovered copper per ton or a millhead grade of 1.33 per cent copper. (calculated at a net recovery of 82%, as at present). The gold and silver content, on the average, amounts to about 33¢ per ton recovered at current metal prices.

The tonnage milled increased from 669,000 in 1926 to 928,000 in 1929, averaging for the five years, 1926 to 1930, 789,000 tons per year. After reopening the mine in 1937 the tonnage rose from 1,223,000 in 1938 to 1,761,000 in 1941, fell off somewhat in 1942 and was further reduced in 1943 to about 1,370,000 tons.

The grade of copper averaged about 1.40 per cent until 1941, when it dropped to 1.285 per cent; it fell to 1.14 per cent in 1942 and about 1.0 per cent in 1943.

The foregoing figures are taken from Departmental records with the exception of the 1943 tonnage and grade which are based on analysis of figures put out by the Company.

Ore Reserves:

The ore reserve sheet furnished by the Company shows a minable reserve of 11.48 million tons at a grade of 1.63 per cent copper. This tonnage will suffer dilution on mining and the Company's estimate is that the dilution will be 51 per cent with material at a grade of 0.35 per cent copper. These are the Company's figures.

Ore Possibilities:

With the possible exception of the Princess May ore-body the ore developed to date lies in a wedge of volcanics bounded on the west by the gabbro contact and on the east by a coarse volcanic breccia. The bottomming of ore-bodies above the 8 level may be the result of the convergence of the breccia and the gabbro. In this zone from 6 level to the surface and from the Princess May southward for about 6,000 feet the gabbro contact has been fairly thoroughly prospected. That other outlying ore-bodies lie to the east of the gabbro contact and are not explored by existing crosscuts and diamond-drill holes appears as a reasonable possibility. An accurate geological concept of the controls of mineralization within this zone would be invaluable to exploration.

Moreover the nature of the rock and the ore possibilities lying east of and beneath the coarse volcanic breccia have not been adequately tested. A considerable volume of completely unexplored ground that has distinct exploratory value could be reached by driving either 10 drift or 30 drift on 6 level farther east and diamond-drilling to both north and south from it. By doing this considerable geological information would be obtained as to the nature of the volcanic rock that lies to the east of the breccia, and would help to unravel one of the major problems of structure. If favorable ground lies east of the breccia it might be expected to intersect the gabbro contact at some depth below 8 level.

Diamond-drill holes for maximum information should be drilled at right angles to the plane of the ore-fractures. Any drilling done more or less parallel to the ore-fracturing direction has small chance of cutting ore for it is possible for a drill hole to ~~to~~ cut longitudinally through an ore-body and yet show low copper mineralization.

by MSH
S.S.

March 1, 1944.

AGE OF MINERALIZATION AND POST-ORE HYDROTHERMAL ALTERATION, COPPER MOUNTAIN, BRITISH COLUMBIA

by

A.J. Sinclair and W.H. White#

ABSTRACT

Unaltered biotites from Copper Mountain stock and a pegmatitic biotite-chlacopyrite vein cutting Triassic Wolf Creek Formation have similar potassium-argon ages of 193 ± 7 m.y. (mean and standard error of the mean). These data indicate a close time relationship between mineral deposition and consolidation of the stock; and support a suggestion based on geological evidence that Copper Mountain ore deposits are related genetically to Copper Mountain Stock.

A cogenetic mineral pair (biotite and clinopyroxene) from sericitized and chloritized monzonite in Copper Mountain Stock have identical potassium-argon ages of 150 m.y. that probably represents a time of widespread, post-ore, hydrothermal alteration. This alteration is genetically related to a group of post-ore intrusions known as "mine dykes". Thus, mine dykes also have an age of 150 m.y.

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