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REPORT

on

GEOLOGY OF COPPER MOUNTAIN MINE

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Outline of geology at Copper Mountain

The Copper Mountain mine lies on the eastern boundary of the Cascade Mountain system in southern British Columbia. The regional geology has been described in Memoir 243 of the Geological Survey of Canada by H.M.A. Rice entitled "Geology and Mineral Deposits of Princeton Map Area, B.C.". A more detailed picture of the geology of Copper Mountain is given in Memoir 171 of the G.S.C. by Dr. V. Dolmage entitled "Geology and Ore Deposits of Copper Mountain, B.C." A report to the company on the geology of the mine was submitted by the writer in April, 1947. The following report gives further detail of the geology of the mine and its significance.

The ore bodies of Copper Mountain occur almost entirely in a series of highly metamorphosed volcanic rocks. These rocks are the products of eruption of a volcano or possibly several volcanoes during Triassic time. The lava flows and ash resulting from the repeated eruptions fell into water and have produced the present thick series of andesites, tuffs and breccias which have been named the "Wolf Creek Series".

Since their original horizontal deposition, the rocks have been folded along north-south axes. The mine lies at the crest of an anticline so the bedding in and near the mine remains essentially horizontal. Possibly during and since folding, the Wolf Creek Volcanics have been invaded by several intrusive rocks. Emanations from these intrusives have resulted in the metamorphism. Economically the most important of these intrusions occurred in Jurassic or Lower Cretaceous time when a body of gabbroic rock came in. This body has been named the Copper Mountain Stock and it has been described by Dr. Dolmage. With it is associated the extensive copper mineralization of the min.e

Before and following the gabbro intrusion, the Wolf Creek rocks and the intrusives were cut by a number of periods of fracturing. Two of these fracture systems are believed to be of importance in controlling the ore location.

Geologists at the mine have long realized that a relation existed between the ore and the character of the wall rock. In a report on ore reserves written by Mr. N. E. Nelson in 1925 while discussing the Wolf Creek rocks, he states: "As now known, the ore bodies are found in certain type rocks of this series, and in these near the contact of a gabbro mass under which the ore bodies plunge". In Don Cannon's report on the geology of the mine dated 1943 he describes an upper and a lower member of the volcanic series.

After preliminary geological work by the writer at the mine the conclusion was reached that most of the ore bodies of the mine were associated with zones of tuffaceous rocks in the volcanic series, where the tuffaceous rocks are cut by other important structures, namely, the gabbro stock, the faults, and certain pre-ore porphyry intrusions. It was realized that before reasonably accurate predictions regarding further ore bodies could be made, the structure of the volcanic rocks would have to be worked out and their stratigraphy organized. Geological research work for the last two years has been directed towards this objective and the following report gives conclusions to date.

Summary of report

Volcanic rocks in and near the Copper Mountain mine have been studied, classified, and assembled into a single stratigraphic column. The sequence of rocks has been found to correspond closely with the sequence which would result from the repeated eruption of a volcano of intermediate type. There are indications that at least four cycles of eruptions have occurred to deposit the rocks now exposed in and near the mine.

Various parts of the volcanic cycle have resulted in the formation of different types of rock which have varying receptiveness to the copper bearing solutions which formed the ore bodies. The second stage, when fine ash and lapilli are settling, has formed stratified tuffs which appear to be especially favourable for ore.

Of the four cycles of volcanism indicated in this area, only two of these favourable tuffaceous members have been located. These two zones have provided the bulk of the ore of the mine to date. Testing for the other suspected zones is now under way by diamond drilling. The upper zone, which has been named B-4 in the stratigraphic table, may show up in the deep drill holes being put down on the Jennie Silkman claim.

The lower unexplored tuff zone, named B-1 on the stratigraphic table may be picked up in the program of deep drill hole work now under way on 8 level in the mine.

Introduction

The concurrence of natural processes which result in the convergence of part of the metallic material of the earth's crust into a mineral deposit of grade and size sufficient to let it be classed as an ore body, is a relatively rare phenomenon. By geological study of an ore deposit some of the processes which have been in operation can be inferred. When these or similar factors are found to occur together in another area, there is a greatly improved chance of finding ore there.

At Copper Mountain certain structures have been identified which are believed to be directly related to the copper ore bodies. These factors have been discussed in a previous report but are listed and briefly summarized below:

Structure	Trend
1. The Gabbro Contact	North-westerly
2. The Main Fault System	"
3. The Ore Fracture System	"
4. Certain Pre-Ore Intrusives	East-west
5. Certain Tuffaceous Members of the Wolf Creek Volcanic Series	Horizontal

The intersection of any three of the five structures listed above will give a point where there is good likelihood of ore. By projecting these known structures into unexplored ground and by recognizing similar parallel structures which may be equally effective, new intersection points can be located.

The gabbro contact

The gabbro contact has long been recognized as one of the most important features at Copper Mountain as about one half of the ore of the mine occurs along it. A recent study of the geology of the mine by Dr. Dolmage suggested to him that a large overhang occurred in the gabbro contact south of the mine. He believed that this overhanging lip may have been present above the present mine, being now removed by erosion, and that it may have been a feature of the gabbro contact which limited and concentrated the copper values. A series of drill holes from the surface were laid out to test the overhang theory and to check the underlying volcanics for copper values. Drill holes JS-2 and JS-3, recently completed on the Jennie Silkman claim about a mile south of the present workings, indicate a possible large overhang of the gabbro. Apparently the contact slopes inwards toward the centre of the gabbro stock at an angle of 40 degrees or less. Some irregular copper values were present but to date ore widths have not been located.

The main fault system

The main fault and its branches are tangential to the curving gabbro contact in the mine but do not cut the gabbro, being entirely in the Wolf Creek series of rocks. About one half of the known ore bodies in the mine are grouped along the main fault or its branches. The fault is essentially vertical and the branches slope steeply in either direction. The trend of the fault is north-westerly parallel to a large cross country fault which lies about four miles away. This large fault is described by Rice and has been named the Otter Fault. It can be traced for about 35 miles north-west from Princeton. Several areas of mineralization are known to occur on the Otter Fault but no mines have been discovered there.

The ore fracture system

The most prominent fracture system in the mine is the ore fracturing. Fractures of this system occur throughout the mine. They trend north-easterly at right angles to the gabbro contact and slope steeply to the north-west. In ore bodies these fractures are especially closely spaced. The copper bearing minerals frequently occur along these ore fractures. The fractures have apparently provided the main channelways for the ore bearing solutions.

Certain pre-ore intrusives.

A system of east-west trending porphyritic dykes composed almost entirely of felspar which cuts through the volcanic series has been found to carry copper minerals near intersections with the main fault system. Other similar intrusives with a different trend are apparently barren.

Certain members of the WolfCreek volcanic series

The features of the Wolf Creek volcanics are much less well defined than those of the other rocks. Variations in texture and composition appear to be closely related tovariations in the copper content of these rocks. Certain zones of the volcanic series appear to be more favourable for copper mineralization than others. Within these zones some beds are well mineralized while others are not. Since the selective process worked on individual beds, it is reasonable to think that it worked in the case of the thicker members of the series and that other favourable zones will lie beyond those already known.

The volcanics of the Wolf Creek series are the oldest rocks of the area. Being the oldest they have been subjected to alteration and dislocation by every succeeding intrusion and ground movement. Each intrusion and ground movement has done something toward obliterating and complicating the original textures and structure of the volcanics. Recent geological work has been chiefly concerned with the project of reconstructing the original picture of the volcanic series.

Structure in the Wolf Creek volcanics

Besides a variety of faults and fractures, a number of structures have been recognized in rocks of the Wolf Creek series which have been used in mapping them. Some of these have important relations to the copper values. The features listed below as primary structures are those which have been used in mapping the volcanics. The secondary structures may be significant as far as the ore is concerned but since they have been developed since the volcanic rocks were formed, they cannot be used in mapping. They must be distinguished from the primary structures for correct mapping and this can only be done with careful work. The following lists show some recognized primary structures and some secondary structures which closely resemble them. A typical occurrence of each feature is also given.

Primary structures

Cherty beds in fragmental formations	240 dr. 6 L
Andesite flow boundaries	60 dr. 4 L
Laminations and grain gradation in tuffs	111 raise
Schisty sedimentary beds	M. dr. 6 L
Pre consolidated slump faulting in tuffs	D.D.Van 42

Secondary structures

Foliation near gabbro contact	Copper Reef M.C.(surface)
Foliation near main fault	60 dr. 5 L
Foliation near pre-ore porpheries	3350 sub.L 122E
Linear elongation of breccia fragments	33 x-cut 8 L
Biotitized pre-ore porphyry sills	Main dr. 5 L
Ore fracturing & pegmatite veinlets	All ore bodies

A study of the primary structural features of the Wolf Creek volcanics has indicated that although some folding occurs, the folds at least in the area near and in the mine are fairly open and symetrical and have a relatively small amplitude. Whether these are small folds which lie along the crest of a large anticline or whether the regional volcanic structure is essentially flat lying remains to be proven. The latter possibility has been gaining increasing favour with work on the geology of outlying areas.

Subsidence and loss of access

Mining operations at Copper Mountain have been laid out so that by following the present stoping plan all of the ore bodies at present shown in the ore reserve will be mineable at full production rate. The method of mining in use here which has been developed to suit ground conditions results in the collapse and subsidence of rock above the ore body as the ore is withdrawn. With the retreat method planned, this will mean that entrance will be lost to all but a small section of the mine near the main shafts when ultimate stages are reached. When new ore is located, the ore bodies will have to be explored, opened up and prepared for production, and inserted in the mining program. If direct access to that area has been lost by that time, long new service tunnels would be necessary to permit its operation. The newly developed 38 block has already raised this problem as its most direct access on 5 level has been cut off bythe mining of 32-34 and 37 blocks and the next closest route in is in danger from 40 block.

Scheduling of ore

Part of the production of the mine can be loaded directly into the ore haulage trains, but a certain amount must be handled by an internal hoist. At present the ratio is about 50:50. At a 5,000 tons per day production rate with present equipment, this ratio cannot be improved since the capacity of the hoist has almost been reached now. Present ore reserves are divided into direct loading and hoisting ore and the 50:50 ratio will permit full extraction of both groups of ore bodies. If new ore is located only in the lower section of the mine the hoisting capacity would have to be increased by a shaft sinking program or eventually production would be limited to the capacity of the hoist.

Since there is still a good chance of finding ore on or above the main haulage level, it is desirable to continue exploration there even though the deep drilling below 8 level shows the best chance of locating new ore.

Ore possibilities below 8 level

For a number of years there wa s a definite feeling in the minds of the staff that the bottom of the mine had been reached at the present 8 level. This idea was founded upon the facts that by that depth all the known ore bodies of the mine had come to an end. Several drill holes were put down below 8 level to depths up to 800 feet in the gabbro contact zone and they only carried traces of copper. These holes were U-627, U-700, U-704 and U-711.

A study of the geology has shown that the lower limits of the known ore bodies correspond with a change from stratified tuff to a coarsely fragmental rock which is apparently an unfavourable wall rock. This zone is about 400' thick. Due to a steepening of the bedding against the gabbro contact, the drill holes put down below 8 level all remained in the unfavourable rock for their entire length.

When the unfavourable rock is penetrated, there is a good chance of locating ore in a lower horizon of bedded tuffs. The immediate problem is to determine approximately how far down exploration willhave to extend before a lower favourable zone is reached. This can be determined directly by drilling. A program of deep drilling is currently under way. An indirect solution can be reached by correlating surface rocks with those of the mine and projecting them below present workings.

The unfavourable horizon

That an unfavourable horizon occurs below presently known ore bodies seems quite definite, but that it is entirely barren of copper values has by no means been proven. Ore bodies which on the upper levels depend upon structures other than the volcanic stratification could be expected to continue through the unfavourable zone with little change. The A-14 ore body and part of the 122-E ore body occur at the intersection of a pre-ore porphyry dyke and faults so they should be continuous. Since the A-14 fracture, the main fault, and the pre-ore porphyry dyke are converging with depth, there is a good chance that where they become close together there will be more intense fracturing and a single larger ore body will occur. Present proposed drilling on 8 level will explore this possibility.

Ore possibilities beyond "A" dyke

Including the new 38 block, ore has been found to extend about 1100' out into the volcanics from the gabbro contact. At this distance 38 block is cut off by the "A" dyke. This dyke is one of the late felsite dykes which occur in the mine. At the 6 level elevation it actually consists of three separate dykes separated by narrow bands of volcanics. The total width of the dyke complex is about 220 feet. Ore occurred beyond this dyke at the surface in glory holes 59 and 63. Some low copper values are known to occur beyond the dyke in drill holes U-282 and U-375, both of which lie some distance south of the possible extensions of 38 block beyond the dyke. There is thus a good chance of finding ore above 6 level beyond the "A" dyke.

Test drilling beyond the "A" dyke is not practical at present due to the distance of this area from possible drill stations. When development for 38 block has been completed, drilling stations can be established in these workings to test the area beyond the "A" dyke.

Surface geological work

A number of extensive exposures of the Wolf Creek rocks occur on the surface near the mine. Careful mapping of these exposures will give additional information on the volcanic rocks which can be coordinated with the information already obtained from underground mapping. A little of this detailed surface mapping was carried out last summer and this summer the work is going ahead with a geological plane table party of two men devoting their full time to it. No exact correlations are possible from this work yet. Reconnaissance work has been carried out over some of the surface exposures. Several of the areas which give promise of interesting information are described below:

Jennie Silkman: On the Jennie Silkman, Rifle and I.X.L. claims, plentiful outcroppings of the Wolf Creek rocks are found. These have been mapped in detail but since they lie about a mile south-east of the workings, correlations with underground geology are impossible until some intermediate work has been done. The rocks mapped there resemble some which occur in the mine but they have been so far considered to belong to a higher level in the stratigraphic column because of the plunge of formations toward the south and the higher elevation of the Jennie Silkman exposures.

Reco: On the Reco and Reco Fraction mineral claims, about 2½ miles south 20 degrees west from the No.1 shaft at the mine, some good outcroppings of the volcanic series occur. These exposures are in the steep lower walls of the valley of the Similkameen River near the south contact of the gabbro stock. A practically continuous exposure can be seen for about 1000' vertically. In this range the rocks vary from cherty and fine grained biotitized rocks to fragmental beds and then to amygdular and ellipsoidal andesites. Insufficient work has been done here yet to determine the attitude of the rocks but indications are that they are relatively flat lying.

Copper Reef: Good outcroppings occur above the C.P.R. track on the Copper Reef claim about half a mile north of the crushing plant near the north border of the gabbro stock. These exposures are about 1500' from the Princess May workings and are about at the elevation of 7 level in the mine. Prominent foliation parallel to the gabbro occurs but a bedding structure can also be seen with a north-south strike and a slope of ten degrees to the east. The exposures show about 400' thickness of cherty rocks and on the indicated dip these beds would be the same cherty rocks as have been found in holes U-796 and U-852 drilled downwards from 8 level in the mine. On the surface these cherty beds appear to be underlain by massive and coarsely amygdular andesites but exposures are poor and further work is required.

Normal sequence in volcanic rocks

A study of present day volcanoes shows that where rocks of intermediate composition are being produced there is a fairly well defined cycle to the volcanic activity. This intermediate type is by far the most prevalent. Volcanic rocks at Copper Mountain are of intermediate composition.

In referring to volcanoes of this type, Pirsson and Longwell state in "Outlines of Physical Geology" as follows:-

> "Their eruptive periods are likely to begin with explosive activity manifested by the ejection of gases in great quantity accompanied by solid fragmental material - bombs and ashes. In a succeeding phase liquid material issues; either it is ejected by the still issuing gases or it breaks through the crater walls and produces outflows of lava, sometimes of great volume. Finally the volcano becomes quiet, its energy for the time being exhausted. The lava column sinks down the conduit and a period of quiescence intervenes before the next eruption."

The cycle may show considerable variation in the duration of each of its parts and in the thickness of rock deposited by each stage. Cycles partly completed might be interrupted by new explosions, but when one stage can be recognized it is probable that all of the preceding stages will be found.

Let us consider the rocks which would result from a volcano of intermediate type if its products were to be deposited in shallow seas such as were believed to exist in this part of the continent during Triassic time. The initial explosion would produce coarse breccia and as the ash and finer products settled through the disturbed waters they would be sorted into a stratified tuff which would be deposited on top of the breccia. The liquid phase would then lay down thicknesses of andesitic lava which might be ellipsoidal or amygduler. When the period of quiescence was reached the waters would be heavily charged with soluble parts of volcanic products, mainly silica which would be deposited on top of the andesites as chert. The sequence is shown in the following table in natural position with the youngest formations on top. The order of deposition is shown by the key letters. In the table three complete cycles are shown:

Table showing a normal volcanic sequence

Key letter	Phase of activity	Type of rock formed
D-3	Quiescence	Cherts, limestones, marine sediments
C-3	Liquid flow	Andesites - pillow lavas, amygdaloids with some flow breccias.
B-3	Gases and solids	Tuff and ash beds.
A-3	Explosive	Coarse fragmental rock in thick beds.
D-2	Quiescence	Cherts, limestones, marine sediments.
C-2	Liquid flow	Andesites, pillow lavas etc.
B-2	Gases and solids	Tuff and ash beds.
A-2	Explosive	Coarse fragmental.
D-1	Quiescence	Cherts, limestones, marine sediments.
C-1	Liquid flow	Andesites, pillow lavas, etc.
B-1	Gases and solids	Tuff and ash beds.
A-1	Explosive	Coarse fragmental.

Stratigraphy of volcanic rocks at Copper Mountain

Because of the complication of the volcanic rocks at Copper Mountain by the offsets of the many faults, the various igneous intrusions, and their related alterations, it has been found impossible to trace any single bed in the series for more than a few hundred feet. When lost, there is little chance of identifying the bed in another area because of the general similarity of the rocks and possibility of lateral variation. However, certain groups of similar beds, or formations, can be identified throughout the area. On the basis of the formations a stratigraphic column has been set up. This column combines the continuous section from the mine workings with more uncertain data from surface work. The column is shown in the following table. Thicknesses shown are approximate. In the table the formations havebeen given key letters which correspond with key letters of similar formations in the table of the preceding section showing an idealized volcanic series. On the basis of copper ore distribution in studied formations in the mine, each formation of the series is given a prospecting classification in the following table. The youngest formations are at the top.

Table of Formations

Key letter	Thickness in feet	Formation	Where exposed	Prospects for ore bodies
D-4	100+	Massive yellowish green chert	Ridge on Rifle MC	Fair?
C-4	400+	Med.and fine grained massive andesites with some flow breccias	Drill holes JS-2 & JS-3 and surface.	Fair to poor ?
B-4	?	Bedded tuffs	Not known	Good ?
A-4	?	Coarse fragmental tuffs	Oriole MC	Poor ?
		-m-		
D-3	?	Massive bedded chert	Not known	Fair ?
C-3	?	Massive andesites	South end of Helen Gardner claim.	Fair to poor ?
B-3	200'	Bedded tuffs	Ore bodies at surface on Sunset & Gardner claim.	Excellent
A-3	150'	Fragmental tuffs	Upper mine 1 level to 2 level	Poor
		-b-		
D-2	?	Chert	Not identified	Fair
C-2	450'	Fine and coarse dark grey andesites with some fragmental horizons marking flow boundaries.	Between 4L & 2 L in mine.	Fair to poor.
B-2	350'	Bedded tuffs	Between 6L & 4L	Excellent
A-2	300'	Coarse fragmental tuff	" 8L & 6L	Poor
D-1	300'	Banded chert	Holes U-796 & U-852 Copper Reef Claim	Fair.
C-1	?	Amygaloid & pillow lavas	Copper Cliff Claim Reco (?)	Fair to poor. ?
B-1	?	Bedded tuffs ?	Not known	Excellent ?
A-1	?	Coarse fragmental tuff	Not known	Poor ?

Conclusions and recommendations

Rocks at Copper Mountain follow a regular recognizable sequence. By means of this sequence it is possible to predict what rocks can be expected beyond present limits of positive knowledge. It will be possible to state whether the rock will be favourable or unfavourable for the finding of ore bodies. It will not be possible to predict the thickness of the formations due to irregularities of the volcanic cycle.

The current program of deep hole drilling will prove the correctness of the preceding conclusions and will give information as to the thickness of the various formations.

The program of detailed surface geological work will give information leading to a more exact correlation between surface outcroppings and the continuous section provided by the mine workings. This work should be continued and it is hoped that it will lead to the location of new ore bodies above the 6 level elevation which will help maintain the ratio of ore to be mined above and below 6 level.

Diamond drilling and geological exploration should be pushed ahead at a maximum rate to assure that any new ore bodies located will be ready for mining when those ore bodies in the present reserve have been exhausted.

Report respectfully submitted,

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