THE ORES OF COPPER MOUNTAIN

BRITISH COLUMBIA

by

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THE ORES OF COPPER MONTAIN

BRITISH COLUMBIA

I. INTRODUCTION AND ACKNOWLEDGEMENTS.

The Copper Mountain Mine whose ores are discussed in this report is a property belonging to the Granby Consolidated Mining, Smelting and Power Company. It is one of the principal copper deposits in British Columbia, ranking third with a production in 1929 of 22,559,798 pounds of copper along with small amounts of gold and silver.

The deposit is situated in the Similkameen District of British Columbia, (Plate I), twenty miles north of the Canada, United States boundary and twelve miles south of Princeton with which it is connected by a good auto road and a branch of the Kettle Valley Railroad both of which pass through Allenby where the mine ores are concentrated. Princeton is 150 miles east of Vancouver.

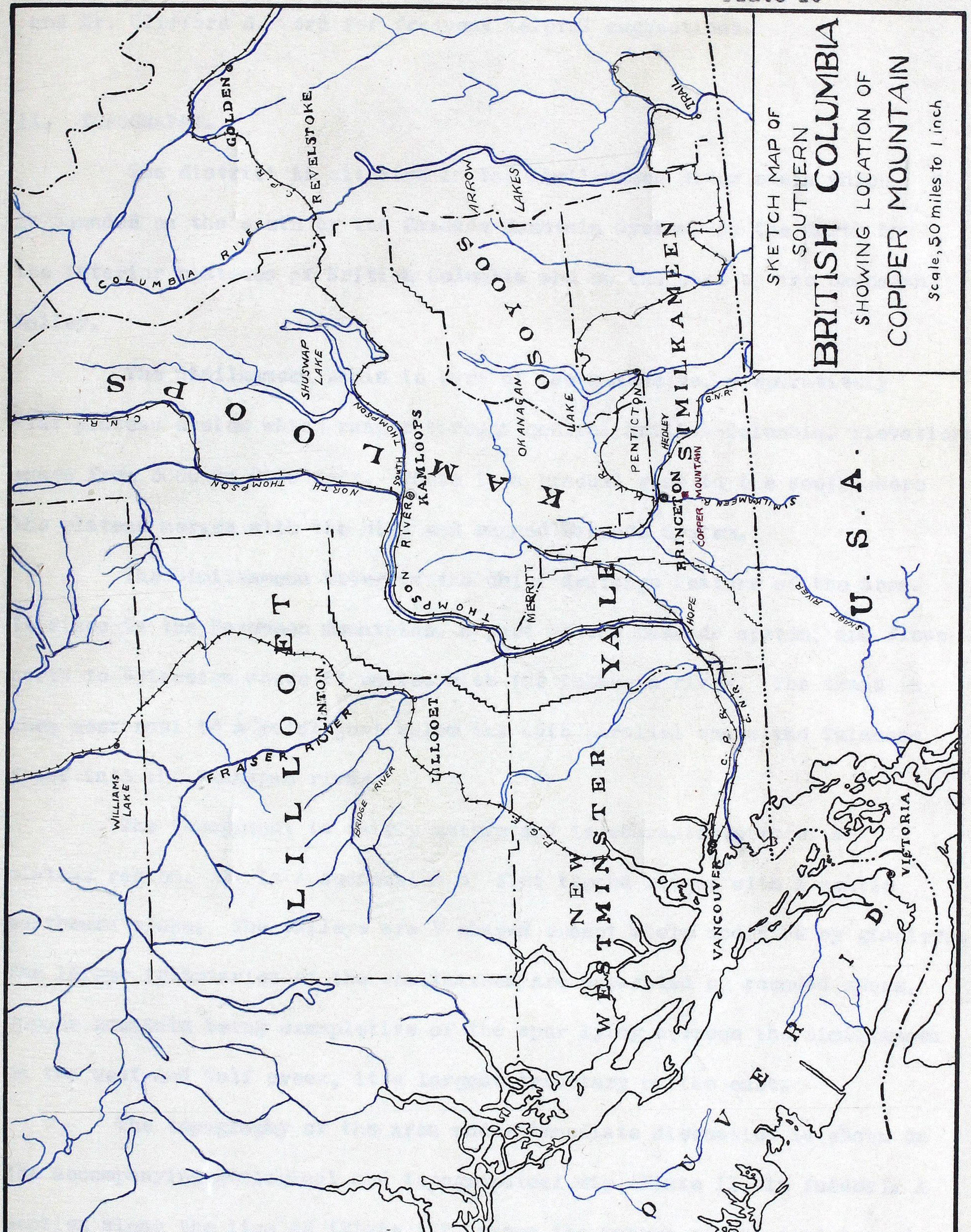
For a detailed description of the physical features, the geology and economic aspects of the area the reader is referred to a publication of the Geological Survey of Canada by Dr. V. Dolmage which is in the course of publication.

The writer is very grateful to Dr. Dolmage under whose supervision this work was done, for help and advice at all times. Acknowledgement is here made of the use given the writer by Dr. Dolmage of his manuscripts and maps on the area. It is freely admitted that a considerable amount of the information profered here has been obtained from Dr. Dolmage either through personal contact or his manuscripts. For all this the writer expresses his thanks. Appreciation is also voiced to Mr. Alexander Smith

PLATE I.

Index map of southwestern British Columbia showing location of Copper Mountain.

Plate I.


SKETCH MAP OF
SOUTHERN
BRITISH COLUMBIA
SHOWING LOCATION OF
COPPER MOUNTAIN
Scale, 50 miles to 1 inch
GOLDEN
REVELSTOKE
COLUMBIA RIVER
ARROW LAKES
OSOYOOS
SIMILKAMEEN
KAMLOOPS
SHUSWAP LAKE
NORTH THOMPSON
SOUTH THOMPSON
THOMPSON RIVER
OKANAGAN LAKE
PENTICTON
HEDLEY
PRINCETON
COPPER MOUNTAIN
SIMILKAMEEN R.
MERRITT
YALE
HOPE
LILLOOET
CLINTON
FRASER RIVER
BRIDGE RIVER
WILLIAMS LAKE
NEW WESTMINSTER
VANCOUVER
VICTORIA
VANCOUVER ID.
U. S. A.
SKAGIT RIVER
TRAIL
C.P.R.
C.N.R.
G.N.R.
P.G.E.
Bella Coola

and Mr. Clifford S. Lord for frequent helpful suggestions.

II. TOPOGRAPHY.

The district is situated in the Similkameen River basin which is bounded on the south by the Cascade Mountain System, on the north by the interior plateaus of British Columbia and on the east by the Okanagan Valley.

The Similkameen basin is part of the extensive, comparatively flat plateau system which ranges through central British Columbia. Elevations range from 3000 to 9000 feet. There is a gradual rise to the south where the plateau merges with the high and rugged Cascade System.

The Similkameen river is the chief drainage feature of the area. It rises in the Hozomeen mountains, a part of the Cascade system, and flows north to Princeton where it unites with the Tulameen river. The trend is then southeast to a point just below the 49th parallel where the Tulameen flows into the Okanagan river.

The topography is fairly mature and is characteristic of a plateau region. It is a succession of flat topped ridges with a gentle northward slope. The valleys are V shaped except where modified by glaciers. The larger tributaries of the Similkameen are separated by rounded spurs, Copper Mountain being exempletive of the spur lying between the Similkameen on the west and Wolf creek, it's largest tributary on the east.

The topography of the area under immediate discussion is shown on the accompanying geological and topographical map (Plate II, in folder). A section along the line AB (Plate III) shows the nature of the flat topped rounded spurs and the V shaped valleys. (Plate IV).

PLATE IV.

Photograph of Similkameen River valley showing a typical V shaped valley. The Similkameen River is entrenching itself in the bottom. Part of the mine workings can be seen in the distance on the left. View looking south.

PLATE IV.

III. GEOLOGY.

GEOLOGICAL HISTORY

The Copper Mountain district is part of a much larger area which is quite similar geologically. This district is bounded on the west by the Coast Range batholith and on the east by Dawson's Shuswap series consisting of Precambrian schists. The Shuswap series is overlain by the Cache Creek series consisting of limestone and other sediments with intercalated volcanics. The Nicola series of probable Triassic age is found above the Cache Creek and consists of volcanics and argillites.

The Wolf Creek formation of probable Triassic age are the oldest rocks encountered in the map area. These rocks occupy a large part of the area mapped, are entirely volcanic and are steeply folded along a northwest-southeast axis.

Extending into the Jurassic are more volcanics and sediments. These are above the Cache Creek series. Above these again are a thick series of fine-grained sediments with a few tuffs, ranging in age from Upper Jurassic to Lower Cretaceous.

Batholithic intrusions on an immense scale took place in the period extending from the late Jurassic to the Tertiary. These intrusions consisting largely of various phases of diorite were responsible for the folding and elevation of the older formations and the subsequent recession of part and the retention of the rest of the marine waters. This resulted in continental sediments of Lower Cretaceous age being deposited.

In Upper Cretaceous time intrusion of batholiths was again the order of events with contemporaneous folding and in some cases overturning of the older rocks. This orogenic movement was followed by erosion, extrusion of lavas and deposition of some continental Tertiary sediments.

The Miocene period was characterized by further orogeny. Intrusions of batholiths and extrusions taking place on a large scale.

These various periods of intrusive and extrusive activity are shown to a certain in the map area. The older Wolf Creek volcanics are intruded by several augite-diorite stocks, the largest and most important economically being the Copper Mountain stock, part of which is exposed in the west central part of the sheet. The Voigt stock occupies a somewhat smaller area in the northeast. This latter stock is probably connected with the Smelter Lake stock a small part of which is exposed in the canyon of the Similkameen river in the extreme north.

Pegmatite and other dykes ranging in age from Mesozoic to Tertiary cut the Wolf Creek formation and the stocks in various places. In the extreme northeast corner is asmaller area of granite known as the Verde Creek granite. Post Oligocene lavas overly the older rocks in the northern part of the area. The thick mantle of glacial materials shows that in Pleistocene time glaciers were active over the region.

LOCAL GEOLOGY

(a) Older Rocks.

The oldest rocks encountered in the map area consist of a series of volcanic flows, tuffs and breccias and are called the Wolf Creek formation. These stocks underly a large part of the area except for two stocks and some younger volcanics in the extreme north. The beds of this formation strike in a northwesterly direction and dip at steep angles.

The series varies over the area. In the south they consist of fine-grained, well bedded and banded dark brown tuffs. Amygdaloidal basalts are exposed in the vicinity south of the Copper Mountain stock in the Similkameen canyon. The Wolf Creek formation in the northern part of the

TABLE OF FORMATIONS

ERA	PERIOD	FORMATION	LITHOLOGICAL CHARACTERISTICS
CENOZOIC	RECENT		Alluvium
		UNCONFORMITY	
	PLEISTOCENE		Glacial Drift
		UNCONFORMITY	
TERTIARY	POST OLIGOCENE	"Tertiary Volcanics"	Flows, Breccias, and necks of Enstatite, Andesite and basalt.
		"Mine Dykes"	Felsite porphyry, quartz porphyry, and Granophyre.
	POST OLIGOCENE?	"Verde Creek Granite"	Granite
		Pegmatite Dykes	Monzonite and Syenite Pegmatite.
MESOZOIC		Voigt Stock	Augite, Diorite, Syeno-diorite (orthoclase diorite).
		Smelter Lake Stock	Augite, Diorite, Syeno-diorite (orthoclase diorite).
		Copper Mountain Stock	Orthoclase- Albite pegmatite
			Syenodiorite (orthoclase-diorite) Monzonite.
			Syenogabbro (orthoclase-gabbro).
		UNCONFORMITY	
MESOZOIC OR PALAEOZOIC		Lost Horse Intusives	Stocks and Sills of Augite, Diorite & Diorite Porphyrite.
	INTRUSIVE CONTACT		
	TRIASSIC?	Wolf Creek Formation	Andesite, Basalt, Trachyte, Breccias, Flows and Tuffs.

map area is made up largely of basaltic flows. A phase of this formation composed of medium to coarse dark green breccias is very important in that it contains the orebodies of the district. This phase consists of angular and rounded green to black porphyritic fragments in a fine grained matrix. Augite and andesine-labradorite are the dominant minerals with minor amounts of hornblende, biotite and magnetite.

Shearing is intense in this formation and pegmatitic material has been impregnated widely.

Dr. Dolmage doubtfully correlates these rocks with Dawson's Nicola Series of Triassic age.

(b) STOCKS. Phases.

Intruded into the steeply folded Wolf Creek formation are two and perhaps three distinct stocks of medium coarse grained material and dioritic in composition. The Voigt and Smelter Lake stocks are probably one and the same, being connected beneath the Tertiary lava flows. The Copper Mountain stock which occupies a large area in the central portion of the district mapped is of prime importance on account of the relation it bears to the ore deposits.

The Copper Mountain stock is 5 miles long by 3 miles wide and strikes northwest. In composition it consists of orthoclase, microcline, plagioclase, augite, biotite, hornblende and apatite; all in varying amounts.

A feature of this stock is its division into three well defined zones consisting of a central core, an intermediate zone and an outer zone. These zones are well shown in the canyon of the Similkameen river which cuts across the centre of the stock. The three zones(Plate III) markedly differ both in texture and composition. Gneissic structures are common in certain parts of the stock and faults with small displacement are frequently

PLATE III.

Cross section along line AB as shown on on accompanying geological map, Plate II (in folder). This section shows type of topography with V shaped valleys, the perpendicular nature of the stock and the relation of the orebodies and dykes to the stock.

(See next page).

COPPER MOUNTAIN AREA

SECTION ALONG AB

Scale, horizontal and vertical – 1 inch to 1000 feet found. The outer zone is fine-grained and ranges from syenogabbro at the margin to syenodiorite on the inner edge where it grades into the intermediate zone. This zone is fairly coarse in texture and varies from syenodiorite to monzonite. The contact between this zone and the core is very sharp and the texture changes to that of pegmatite. Acessory minerals such as augite and biotite disappear or are present only in small quantities and the dominant minerals are those of the feldspar group along with apatite as the acessory. Small amounts of chalcopyrite and bornite are scattered in this zone.

The stocks in the northern part of the area are quite similar in mineral composition to the Copper Mountain stock,but differ in that they are uniform in character. On account of their homogeniety they are probably somewhat later in age than the Copper Mountain stock. The Voigt stock extends over a fairly wide area in the northwest part of the area while the Smelter Lake stock occupies only a very small part in the canyon of the Similkameen but extends for some distance to the north. These two stocks are probably joined beneath the Tertiary lavas which appear to separate them. They consist of dark grey medium-grained augite diorite or syenodiorite.

(c) OTHER INTRUSIVES.

In the northern part of the area in the vicinity of Lost Horse gulch are irregular and poorly exposed intrusions consisting of light colored augite-diorite and pinkish grey monzonite or syenite. They are largely in the form of dykes and contain minor amounts of pyrite and chalcopyrite. This mineralization probably originated from the stock magma as did these intrusives. They are termed the Lost Horse Intrusives and are slightly older than the stock.

In the areas adjacent to the stock are found syenitic pegmatite dykes made up of orthoclase, albite, biotite and augite along with disseminated bornite and chalcopyrite. This pegmatitic material has been injected into the sheared and fractured volcanics of the Wolf Creek formation in the form of dykes. Insomuch as the pegmatites cut the stocks they are older, but like the Lost Horse Intrusives they are similar in mineral composition and relation to the stock and thus no doubt of the same origin.

A large number of white and creamy white granophyre and felsite porphyry dykes known as the "Mine Dykes" (Plate V) are plentiful in the area, especially in the region adjacent to the Copper Mountain and Voigt stocks. They hinder efficient mining to a considerable extent in the Copper Mountain Mine. These dykes extend for considerable distances, vary width up to 150 feet and divide into branches and come together again. These dykes trend north and south and dip vertically as shown in Plate III and Plate VI. The texture and composition are quite uniform. They cut the several stocks so are evidently older. The dykes themselves are cut by fine grained amygdaloidal andesite dykes which also cut the stocks. These latter dykes are at right angles to the "Mine Dykes".

A large body of reddish granite is intruded into the rocks of the district, a small part of which extends into the extreme northeast corner of the map area. The granite is high in quartz content which distinguishes it readily from the rest of the rocks of the region. It is termed the Verde Creek granite and is older than the Voigt stock as it cuts it. On lithological grounds Dr. Dolmage correlates it with Camsell's Otter Creek granite of Post Oligocene age.

PLATE V.

Photograph of glory-hole at the Copper Mountain Mine with large light colored "Mine Dyke" well shown in the centre of the picture. In the lower part of the photograph fracture and foliation planes are shown.

PLATE V.

PLATE VI. FIG. I.

Photograph of glory-hole at the Copper Mountain Mine . The vertical dip of the "Mine Dykes" is brought out in this photograph.

PLATE VI. FIG. 2.

Photograph of glory-hole at Copper Mountain. Note mantle of glacial debris.

PLATE VI. FIG. I.

PLATE VI. FIG. 2.

(d) EXTRUSIVES.

Dense fine-grained amygdaloidal flows and also tuffs and breccias occur in the northern part of the area. These overly the Wolf Creek formation unconformably and outside the area overly Oligocene sediments conformably.

IV. ORE DEPOSITS.

(a) STRUCTURE.

The foliation and fracturing which occurred as a result of stresses after intrusion of the Copper Mountain stock created channels for the passage of the ore bearing solutions. These foliation planes and the fractures control the tenor of the ore to a marked extent. As the stock slowly cooled pegmatitic material was exuded from the practically congealed magma resulting in the formation of pegmatite dykes which penetrated the Wolf Creek formation. This was followed by the hydrothermal stage and the subsequent deposition of the ore along the fracture and foliation planes. Still later the "Mine Dykes" were intruded and these are directly responsible for the present structure of the ore deposits.

The "Mine Dykes" , later in age than the pegmatite dykes and ore bearing solutions, probably originated at depth while the parent magma of the stock was still liquid. Possibly they followed up fracture planes parallel to the stock to the earlier pegmatite dykes and the orebodies. These fracture planes might be caused by tension following the cooling and solidification of the magma near the stock.

The foliation and fracturing extend over a zone several hundred feet wide and parallel to the length of the stock along the northeast contact.

The dykes have cut into the mineralized breccias of the Wolf Creek formation. They are peculiar in the way they divide and come together again. On account of this they might be termed "lode dykes" due to their similarity to a characteristic lode vein which shows the same tendencies. On the surface these dykes divide the mineralized breccias into a series of orebodies which lie between the perpendicular walls of the dykes. The mineralization is cut off at the inter-section of the dykes. The edge of the mineralization and the walls of the dykes are coincident in most cases in the immediate vicinity of the stock contact. These facts are well shown in the plan on Plate VII where the orebodies on the surface are outlined.

The orebodies on the number 2 level are also indicated. These in most cases lie directly beneath the surface showings but are much smaller in size. This gives some of the orebodies a perpendicular form tapering at depth.

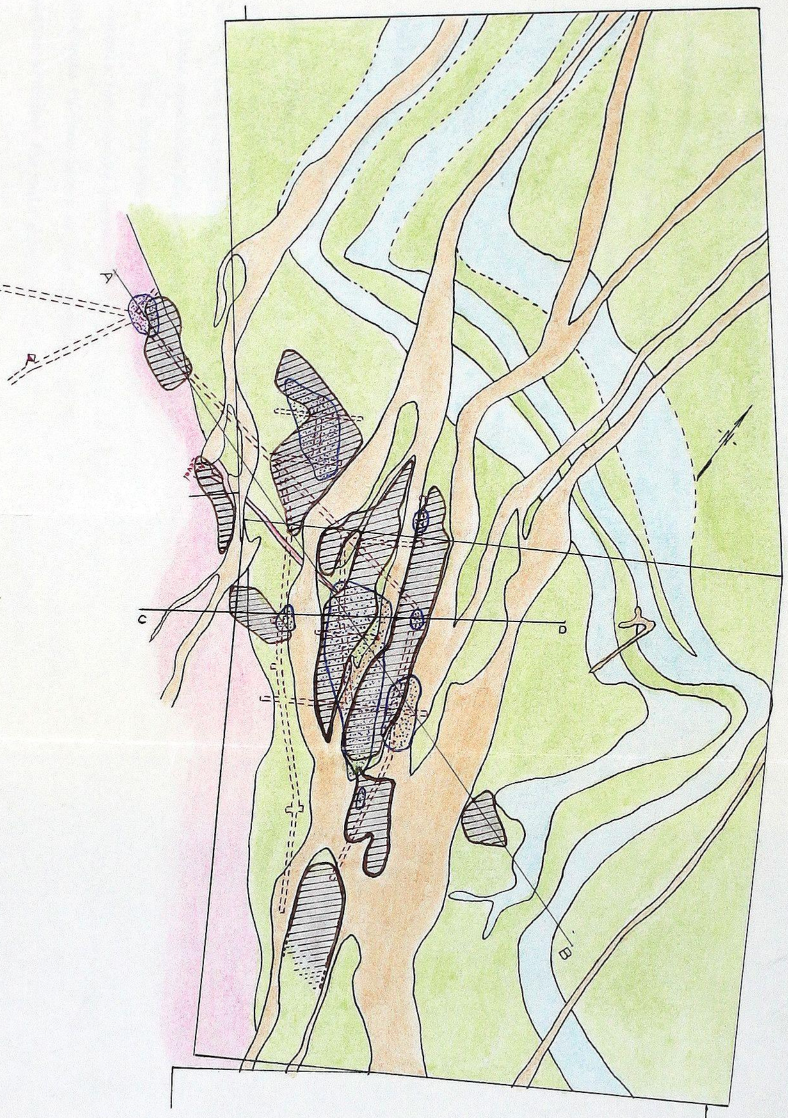
In the cross sections on Plate VII the relation of the orebodies to the "Mine Dykes" is depicted. The dykes have divided the mineralized breccias up into a number of smaller orebodies. On the fourth and fifth levels in the mine another orebody is encountered lying against the stock contact. This orebody has not been affected by the "Mine Dykes"; it's extent being controlled by the fractures.

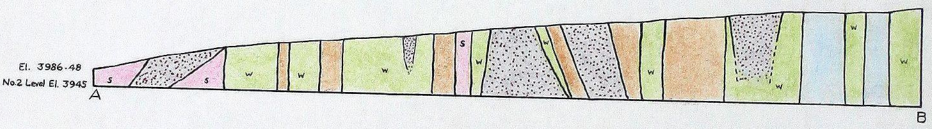
Two of the main orebodies are shown to be continuous from the surface to the fifth level at least in the sections. They are bounded by the "Mine Dykes". These two orebodies were in all probability one complete mineralized zone until the intrusion of the dykes which resulted in the division into two separate bodies.

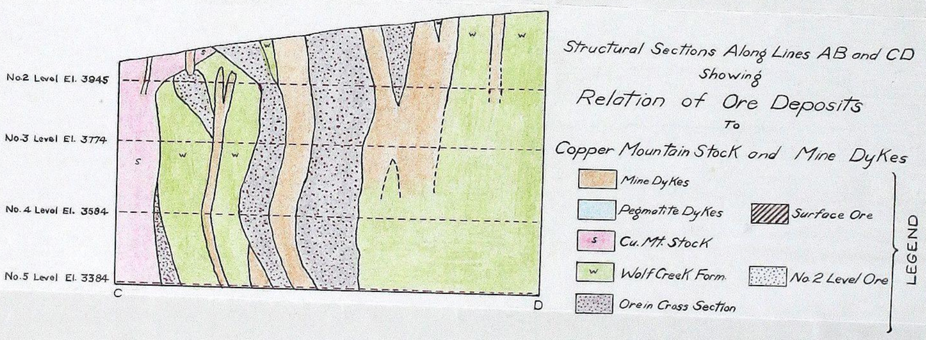
The foliation planes lie parallel to the stock while the fractures

PLATE VII.

Plan and cross sections of Copper Mountain orebodies showing their relation to the "Mine Dykes" and the contact of the Copper Mountain stock. (See next page).







GEOLOGY AND STRUCTURE

OF

ORE DEPOSITS

AT

COPPER MOUNTAIN MINE

Scale 1 inch = 300 feet

are in a direction at right angles to these. It is believed that the foliation planes formed the lines of weakness by which the "Mine Dykes" made their way into the mineralized breccias in this vicinity. The sections on Plate VII clearly show the relation between the stock contact and the dykes.

Adjacent to the ore deposits but not affecting them to any extent are several small fault zones striking north and south.

It is evident then that the shape, breadth, and pitch of the orebodies owe their characteristic structure to a large degree to the "Mine Dykes" which have penetrated the mineralized breccias of the Wolf Creek formation in this locality.

(b) FRACTURES.

As a result of some form of stress the breccias of the Wolf Creek formation have been intensely fractured. This fracturing is not uniform but varies in intensity in different parts of the formation. These fractures are vertical and normal to the contact of the stock, thus they strike at right angles to the foliation.

The fractures are straight and approximately parallel to one another (Plate VIII). In width they vary, but most of them are quite small and do not exceed an eighth of an inch. In some of the material studied the fractures were more than an inch apart and quite regular while in other specimens the fractures were extremely close together and short.

The fractures are exceedingly important in that they provided the channels for the ore bearing solutions. They allowed the solutions to penetrate to many parts of the breccias. The larger fractures and foliation planes afforded the main channels, while the smaller and more indistinct

PLATE VIII.

Massive block of Copper Mountain ore showing parallel fractures.

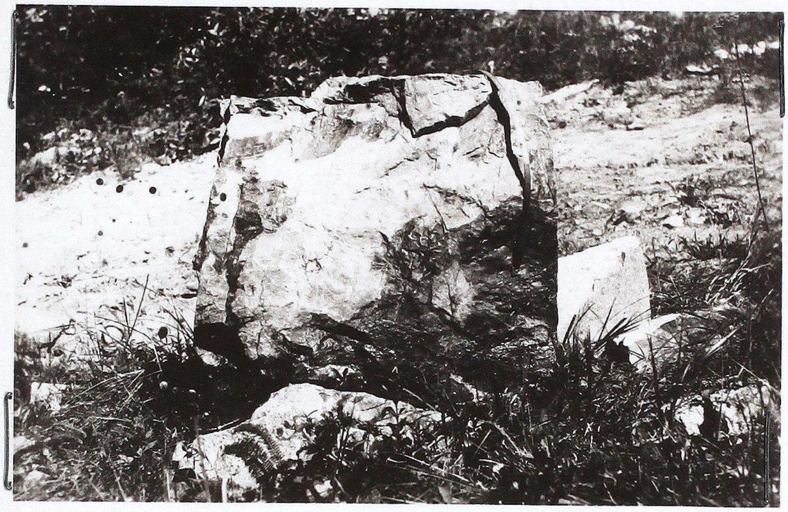


PLATE VIII.

ones permitted the mineral bearing fluids to spread throughout the rock.

The copper minerals of the main mineralization period were deposited in these fractures, hence the grade of the ore depends on the size of the fractures and the frequency with which they occur.

The fractures are not confined to the Wolf Creek formation alone but are found also in the Copper Mountain Stock, principally in the vicinity of the ore deposits. They are also found in the intermediate zone of the stock and near the pegmatite-intermediate zone contact. These are mineralized to a certain extent also.

A peculiarity of the fracture system is the fact that it is almost entirely absent in some places, while immediately adjacent , the opposite is true. In the cross sections on Plate VII the unmineralized portions of the Wolf Creek formation between the dykes and adjacent to the stock contact are found to be free from fractures.

The fractures are earlier than the period of ore deposition and somewhat later than the stock intrusion. The stresses that caused them were probably active over a period of time. The period of stress that produced the wider and more consistant fractures being somewhat stronger than that portion of the period which produced the smaller ones. The fact that the fracture system is in zones is also indicative of a longer period of stress.

A large number of the fractures are filled with pegmatitic material. This is particularily true of the larger ones and the material is essentially felspar(orthoclase) and mica with minor amounts of epidote, augite and apatite. Quartz is entirely absent. Thus the pegmatitic material in the fractures is syenitic.

Concentrated along the centre of the pegmatite veinlets which fill the fractures are important copper minerals consisting of, bornite, chalcopyrite, chalcocite, and covellite. These minerals which are formed more or less in a line down the centre of the vein are of slightly later age (Plate IX) than the pegmatite material as they extend beyond the pegmatite veins and further into the fractures.

The smaller fractures have not been intruded by the pegmatitic fluids but they are mineralized with bornite and chalcopyrite.

Later calcite veinlets also penetrated these fractures, chiefly down the centre, and in many places extended beyond the pegmatite.

(c) RELATION TO COPPER MOUNTAIN STOCK.

The ore bodies of the Copper Mountain Mine occur adjacent(Plates III and VII) to the contact of the Copper Mountain stock in breccias of the Wolf Creek formation. They are situated on the northeast side of the stock and are in the form of several distinct orebodies which are parallel, both to each other and to the stock contact.

Following the intusion of the Copper Mountain stock and previous to it's hydrothermal stage, foliation and fracturing took place as a result of stresses. It is clearly evident that these minor structures were formed after the intrusion, and as the ore is largely confined to them, they are thus previous to the hydrothermal stage of the stock which was responsible for the ore deposition.

That the orebodies are genetically related to the stock is indicated by the close proximity between these bodies and the stock. The presence of pegmatitic material in the fractures in the breccias which is of the same composition as the pegmatite core of the stock indicates a common origin. The absence of quartz in both of these is significant. A further

PLATE IX.

Camera lucida drawing of Copper Mountain ore showing hypogene bornite. The deposition of the bornite has been controlled by the pegmatitic material in the fractures. Magnification X 54.

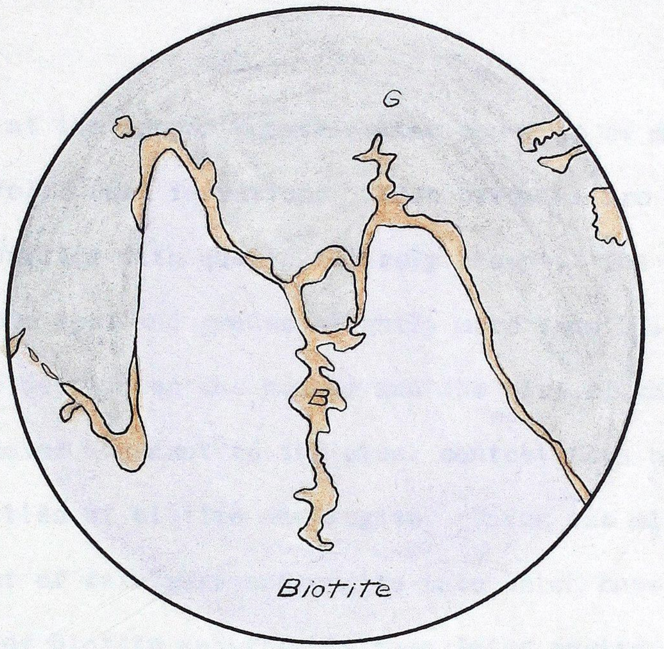


PLATE IX

indication of the genetic relationship is the presence of bornite and chalcopyrite in the fractures in the stock, the pegmatitic core, and as ore minerals in the breccias.

(d) COMPOSITION.

ORE.

The ore at the Copper Mountain Mine consists of mineralized breccias of the Wolf Creek formation. These breccias are andesitic and basaltic in composition with quartz entirely absent. The deposit is of the contact metamorphic type and grades slightly more than 2%. As has been stated this grade depends on the number and the size of the fractures.

The breccias adjacent to the stock contact have been impregnated with large quantities of biotite and augite. Under the microscope the rock is seen to consist of feldspars and augite into which have been introduced large quantities of biotite andprobably some later augite. This zone of biotite and augite is not uniform, some parts being almost free from the impregnation while in other parts the biotite and augite are so intense that it is difficult to interpret the original characters of the rock. It occurs previous to the fracturing at the biotite and augite are absent from the fractures.

Disseminated in the biotitized rock is found bornite and chalcopyrite along with magnetite. The magnetite may be an original constituent of the rock but it is more probable that it was introduced into the rock along with the bornite, chalcopyrite, biotite and augite. The bornite and chalcopyrite are important but without the later period of metallization they would not be in sufficient quantities to make the breccias an ore.

Following the period of fracturing and foliation, into the main rock mass to a certain extent, and especially into the fractures was intruded pegmatitic material and copper bearing solutions.

The pegmatitic material was the first to enter the fractures. It consisted of albite, oligoclase, microcline, mica, epidote, augite and apatite. Some of these minerals along with the alteration products have penetrated the rock on each side of the fractures, especially the larger ones. The result is a light colored zone. These zones are white to greenish in color adjacent to the fractures, while a ¼ of an inch away the color has gradually faded and the zone appears to merge with the rest of the rock. The minerals in this zone are very fine and difficult to determine. It appears as if they have literally plugged the rock as copper minerals, magnetite and hematite are almost entirely absent.

Slightly later than the introduction of the pegmatitic material and after it had cooled slightly and contracted to a certain extent, copper rich tenuous solutions followed along the fractures and down the centre of the veinlets that fill the fractures and deposited important minerals. The The mineralization consists of bornite, chalcopyrite, chalcocite, hematite and covellite. These minerals are concentrated along the centre of the pegmatites in a fairly continuous line. Small amounts of these minerals are disseminated throughout the pegmatite also.

The zones bordering the pegmatites have prevented the passage of the ore solutions into the surrounding rock in their immediate vicinity. In these areas it was noted that there was a heavy concentration of minerals in the veinlets, while immediately adjacent, mineralization was almost entirely absent.

In the smaller fractures pegmatitic material is absent to a large extent, often only a few scattered crystals being found. However the tenuous solutions penetrated these fractures and bornite, chalcopyrite, and some chalcocite was deposited. Supergene chalcocite, covellite, and chalcopyrite are absent from the smaller fractures.

In some areas magnetite and hematite are concentrated. Where this is the case, copper minerals are nearly always absent. The ore is almost entirely free from pyrite, it being noted in only a few instances.

About half of the ore supply is obtained by glory-holing (Plate VI), the remainder by underground stoping and developement.

GANGUE.

The gangue material in the Copper Mountain ore consists of the minerals of the altered breccias of the Wolf Creek formation. These breccias are andesitic to basaltic. The minerals composing the gangue are: various feldspars, augite, biotite, epidote, apatite, magnetite, hematite, sericite and other alteration products, calcite, and possibly some chlorite.

The "Mine Dykes" where they penetrate and cut the orebodies are waste and have to be mined in most cases as they are not strong enough to stand alone.

ALTERATION.

The breccias have been intensely altered by hydrothermal solutions eminating from the stock magma. Replacement has widened the fractures in many places and the minerals have been attacked by these solutions. The alteration consists of biotite, augite, sericite, calcite, and some epidote and zoisite?.

Biotite and augite are widely spread throughout the breccias. The ferro-magnesian minerals have been altered to sericite, and the orthoclase feldspars to sericite and calcite. The alteration of the plagioclase feldspars by the breakdown ofthe solid solution of albite and anorthite into a dense aggregate composed of albite or orthoclase and zoisite or epidote, along with variable amounts of calcite, sericite, and calcium-aluminum silicates other than those of the epidote group is termed sausseritization by Williams#. It appears that this is the type of alteration that has

Williams, G.H. U.S. Geological Survey, Bull. 62. page 67.

taken place in the Wolf Creek breccias to a certain extent.

Orthoclase being the most resistant of the feldspars to alteration, it is as a result the most easily distinguishable and the one freest from alteration. Apatite crystals have not been attacked and stand out clearly. The apatite is confined to the altered zone.

Alteration and bleaching by sericite is most common in the vicinity of the fractures. This is probably responsible for the whitening of the zones adjacent to the fractures. This alteration is distinctly later than the augite and biotite.

(e) MINERALOGY AND PARAGENISIS.

The paragenisis of the ore at the Copper Mountain Mine determined from the study of sections is as follows:

HYPOGENE	EARLY	MAGNETITE BORNITE CHALCOPYRITE
	LATE	HEMATITE PYRITE BORNITE CHALCOPYRITE CHALCOCITE CALCITE
SUPERGENE		COVELLITE CHALCOCITE CHALCOPYRITE

MINERAL	HYPOGENE		SUPERGENE
	EARLY	LATE	
MAGNETITE	—		
HEMATITE		—	
PYRITE	—		
AUGITE & BIOTITE	—		
BORNITE	—	—	
CHALCOPYRITE	—	—	—
CHALCOCITE		—	—
PEGMATITE IN FRACTURES	—	—	
CALCITE		—	
COVELLITE			—

The sequence of events is indicated in the following summary.

I. Wolf Creek formation intruded by the Copper Mountain Stock.

2. Dissemination in the breccias of the Wolf Creek formation of magnetite, bornite, and chalcopyrite and the alteration of the breccias by the injection of large amounts of biotite and augite.

3. Period of fracture and foliation.

4. Pegmatitic material injected into some of the fractures and further alteration and plugging of some of the channelways.

5. Late hypogene mineralization.

6. Calcite veinlets.

7. Supergene mineralization.

Magnetite:

In the Copper Mountain ore magnetite occurs as an acessory mineral resulting from magmatic differentiation and is pyrogenetic in origin. The magnetite is fairly well scattered throughout the ore with local concentrations.

Bornite:

The bornite at the Copper Mountain Mine is one of the most important sulphide minerals. It is entirely hypogene in origin and is associated with chalcopyrite and chalcocite. In the early hypogene stage bornite is found disseminated through the breccias along with chalcopyrite. This mineralization is not intense enough to form ore. The breccias at this stage being in reality a protore. In the late hypogene stage bornite is found associated with chalcopyrite and chalcocite.

Chalcopyrite:

Along with bornite, chalcopyrite forms the most important mineralization. It is found with bornite disseminated in the breccias, with bornite in the fractures, and as a supergene mineral along the calcite veins and projecting as blades and segregated laths in bornite. The relationships between chalcopyrite and bornite are discussed later.

Hematite:

Hematite occurs frequently associated with magnetite but definetly later. It replaces the magnetite both marginally and internally (Plate A, Fig. I). It's relationship to other mineralization is more difficult to determine. In one specimen in particular that was studied it is quite apparent that hematite is previous to the later bornite and chalcopyrite. The criteria indicating this being, the presence in pits of the hematite of blebs of bornite, and in some places the bornite being replaced by chalcopyrite.

Where bornite borders hematite; under high magnification it is noticed that a very thin rim of chalcopyrite separates it from the hematite. This is indicative no doubt of later chalcopyrite and bornite.

The hematite is confined largely to the altered zone. The solutions carrying the hematite used the fractures as channelways, but evidently found difficulty in penetrating to any distance from these fractures due to the concentration of pegmatitic material and alteration products in and adjacent to the fractures, and the consequent plugging of any channels that might have existed.

Hematite was found occurring as distinct blades in the gangue material(Plate X, Fig.2). It was evidently affected by later calcite.

Pyrite:

Pyrite is conspicuously absent from the ore, it being noted in only a few instances and then in only small particles and under high magnifications. Where noted it appears to be hypogene. It is found as residual remnants in hematite and early bornite.

Chalcocite:

Chalcocite is abundant as a hypogene mineral and is found with bornite in the fractures. Superegene blue chalcocite occurs in smaller quantities as veinlets traversing chalcopyrite and bornite in fractured zones, and to a certain extent with the disseminated bornite. The supergene chalcocite was formed as a product of the replacement of chalcopyrite and bornite. The hypogene chalcocite bornite relations are discussed at greater detail subsequently.

Calcite:

One of the last stages affecting the ore deposit was the intro-

PLATE X. FIG. I.

Camera lucida drawing showing hematite(H) replacing magnetite(M). Magnification X 275.

PLATE X. FIG. 2.

Camera lucida drawing showing blades of hematite(H) in gangue(G). Chalcopyrite(Cp) on edge of field. Magnification X 275.

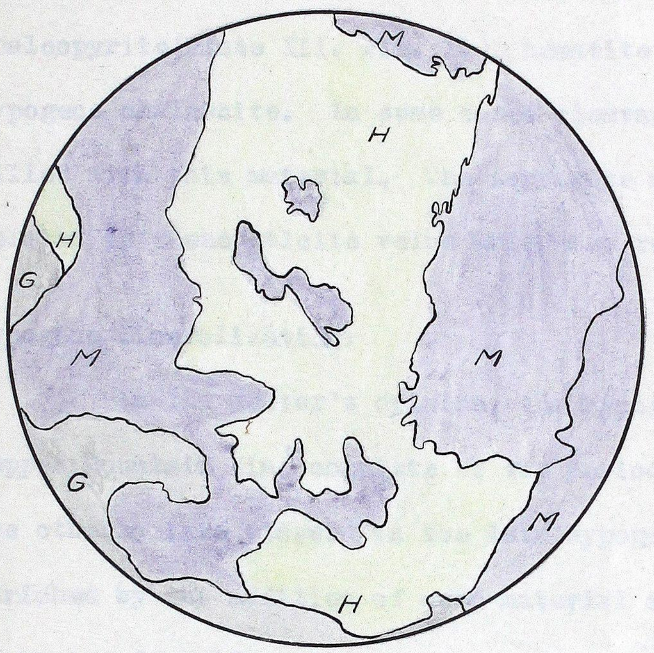


PLATE X. FIG. I.

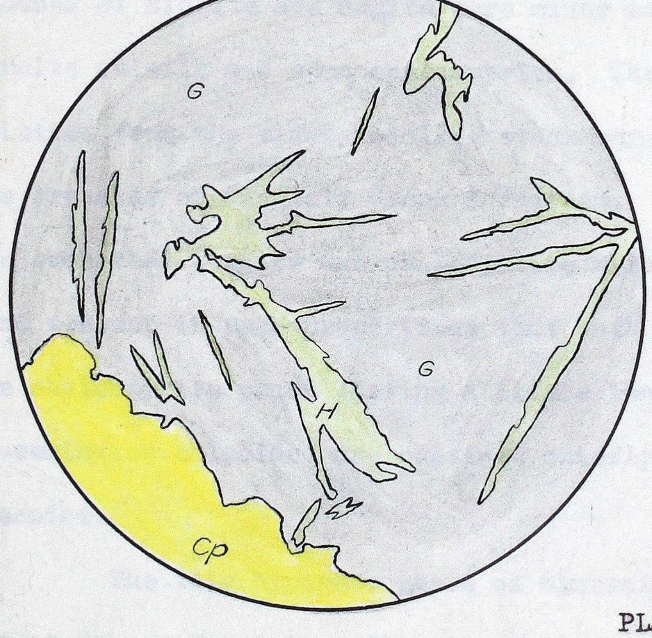


PLATE X. FIG. 2.

duction of calcite. The calcite in the form of veins, intricately cuts all the minerals except those of supergene origin. Calcite veins cut across and are later than, bornite(Plate XI. Fig. I.), magnetite(Plate XI. Fig. 2), chalcopyrite(Plate XII. Fig. I.), hematite(Plate XII. Fig. 2.), and hypogene chalcocite. In some cases cleavage cracks in bornite have been filled with this material. The supergene mineralization is directly related to these calcite veins which are reticulate in form.

Hypogene Mineralization:

In the writer's opinion, the hypogene mineralization at the Copper Mountain Mine consists of two periods; the one an early stage and the other a late stage. In the late hypogene stage the early protore was enriched by the addition of more material and this resulted in the formation of an ore deposit.

The early hypogene stage of mineralization occurred previous to the fracturing and foliation. Associated with the introduction of large amounts of biotite and augite were minor amounts of sulphides consisting of bornite chiefly and some chalcopyrite. These sulphides were carried in solution from the slowly cooling stock magma and disseminated throughout the breccias of the Wolf Creek formation. The composition of these solutions was such that bornite and chalcopyrite were deposited. Iron and sulphur were present in such proportions that both minerals were precipitated with the chalcopyrite phase lasting a little longer than the bornite. These disseminated sulphides are confined chiefly to the altered zone of the breccias.

The late hypogene phase of mineralization is responsible for the ore at Copper Mountain. Into the fractures and foliations of the breccias copper rich solutions penetrated and deposited bornite, chalcopyrite and

PLATE XI. FIG. I.

Camera lucida drawing showing calcite crystal in hypogene bornite. This indicates that calcite is later than bornite.

Magnification X I50.

PLATE XI FIG. 2.

Camera lucida drawing showing calcite vein cutting across and later than magnetite and the gangue.

Calcite(C). Magnetite(M).

Magnification X 275.

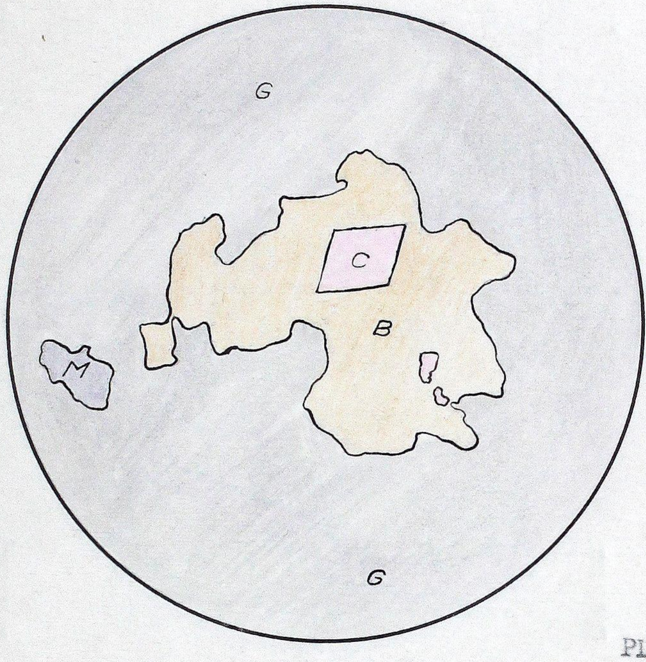


PLATE XI. FIG. I.

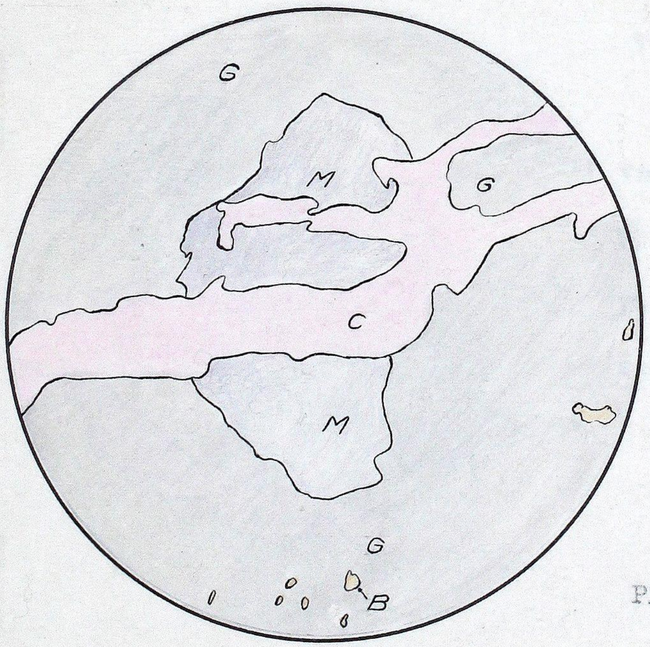


PLATE XI. FIG.2.

PLATE XII. FIG. I.

Camera lucida drawing showing vein of calcite(C) later than chalcopyrite(Cp).
Magnification X 85.

PLATE XII. FIG. 2.

Camera lucida drawing showing veins of calcite later than chalcopyrite(Cp) and hematite(H). Note the parallelism of the walls of the calcite veins. Magnification X 85.

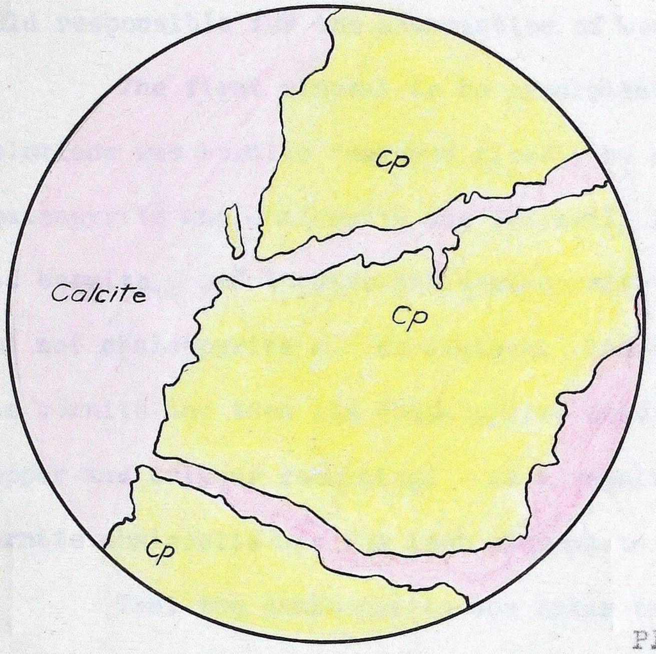


PLATE XII. FIG. I.

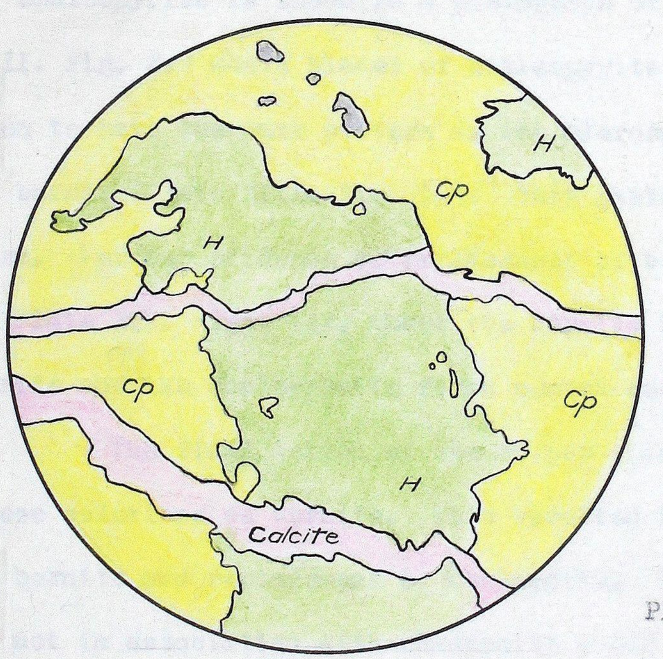


PLATE XII. FIG. 2.

chalcocite in fairly large amounts. The sulphides in these fracture zones occur chiefly in massive form with slight amounts disseminated in the pegmatitic material which encloses the veinlets. The absence of pyrite is held responsible for the association of bornite, chalcopyrite, and chalcocite.

The first mineral to be precipitated out of the penetrating solutions was bornite followed closely by chalcopyrite and chalcocite. The chalcopyrite and chalcocite are definetly later than the bornite. Chalcocite and bornite, and bornite and chalcopyrite are found associated together but not chalcopyrite and chalcocite. The tenuous solutions that deposited the bornite and then the chalcopyrite were depleted in iron with only copper and sulphur remaining. As a result of this and the breakdown of bornite chalcocite was the last mineral to be precipitated.

That the chalcopyrite was later than the bornite is definetly established. It rims the bornite and lines of chalcopyrite follow cleavage planes in bornite(Plate XIII. Fig. I.). The massive replacement of bornite by chalcopyrite is shown in a photograph of a polished section of ore(Plate XIII. Fig. 2.) where blades of chalcopyrite as much as an inch in length are seen to have the same pattern as the microscopic blades of chalcopyrite in bornite(Plate XIII. Fig. I.). This pattern is somewhat triangular in form. Further evidence of replacement of bornite by chalcopyrite is shown in Plate XIV. Figs. I&2, where the bornite is "bitten" into by the chalcopyrite and the chalcopyrite forms convex curved outlines against the bornite.

The final action of the copper rich solutions was the attack by these solutions on bornite. This resulted in the partial breaking down of bornite and replacement by chalcocite. The fact that the chalcopyrite is not in association with chalcocite would seem to indicate that it is a case of selective association, with the bornite being the subject of

PLATE XIII. FIG. I.

Microphotograph showing lines of chalcopyrite(light grey) following cleavage planes in bornite(dark grey), also chalcopyrite rimming and eating into bornite. All indicative of later chalcopyrite. The gangue is black. Magnification X 550.

PLATE XIII. FIG. 2.

Photograph of polished surface of ore showing large blades of chalcopyrite in a triangular pattern. This is indicative of massive replacement of bornite by chalcopyrite.
Magnification X 2.

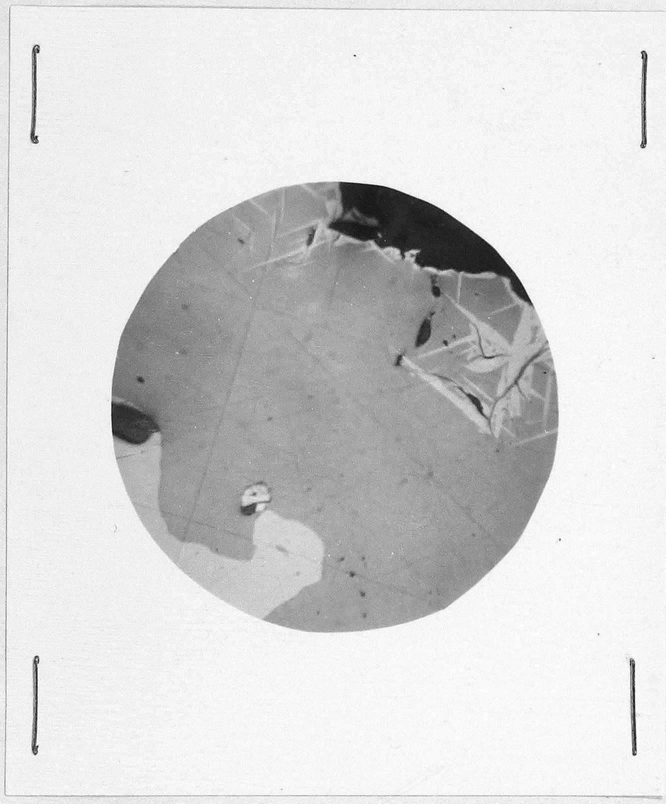


PLATE XIII. FIG. I.

PLATE XIII. FIG. 2.

PLATE XIV. FIG. I.

Camera lucida drawing showing bornite(B) being "bitten" into and replaced by chalcopyrite(Cp). Note curved convex outlines of chalcopyrite against bornite.
Magnification X 550.

PLATE XIV. FIG. 2.

Camera lucida drawing showing chalcopyrite later than bornite. The chalcopyrite forms convex outlines against the bornite and a long tongue of chalcopyrite extends into the bornite. Hematite(H). Gangue(G).
Magnification X 275.

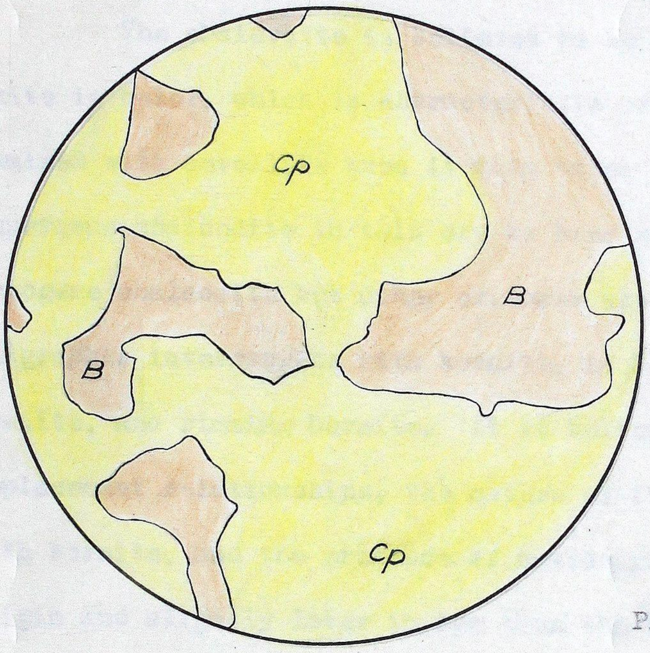


PLATE XIV. FIG. I.

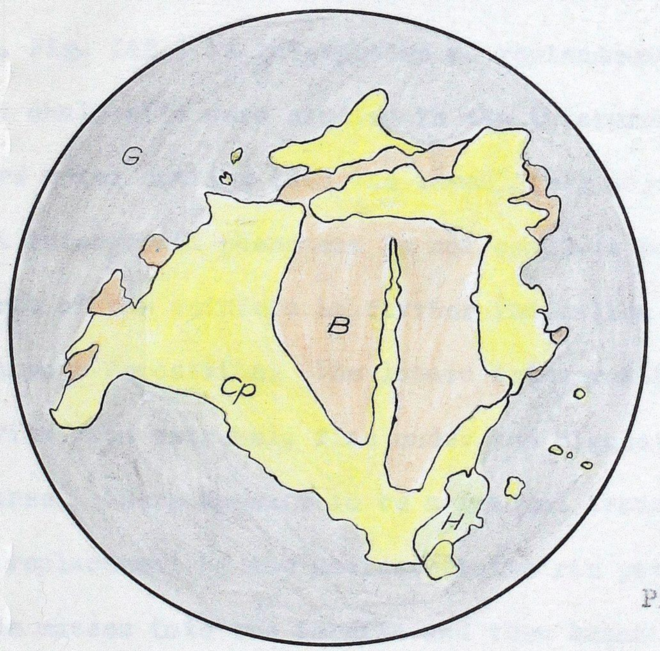


PLATE XIV. FIG. 2.

replacement. If the chalcocite were previous to the chalcopyrite, it would be expected that it would at least be "rimmed"by it in it's rim association with bornite.

The chalcocite is believed to be hypogene in origin. It is clear white in color, which is characteristic of hypogene chalcocite unless admixed with covellite when it then takes on bluish tinge in places. The supergene chalcocite in this ore is blue and this distinguishes it from the hypogene chalcocite but other criteria are used. The chalcocite is found in graphic intergrowths with bornite, in blades or laths cutting across bornite, and rimming bornite. It is believed that as a result of these replacement relationships, the nature of the chalcocite and it's association with bornite, and the presence of chalcopyrite, that it is hypogene in origin and slightly later in age than the bornite.

The deposition of all three of these minerals is probably a case of successive overlap.

The graphic intergrowth between the bornite and chalcocite(Plate XV. Fig. I&2.) is interpreted as replacement. In most cases where bornite and chalcocite were studied in the intergrowths, fine veinlets of chalcocite were noted cutting into the immediately adjacent bornite. The fact that the intergrowth phenomena is not complete but is found only in certain parts of the veinlets is further indication of replacement and not contemporaneous deposition. The lobate intergrowth between these two minerals varies from extremely fine under the highest powers obtainable to quite coarse. There appears to be a gradual transition from graphic intergrowth to replacement by the characteristic rim pattern. The chalcocite extends in wide masses into the bornite and then branches out on the sides into the characteristic lobate replacement. Veinlets of chalcocite traversing bornite

PLATE XV. FIG. I, and FIG. 2.

Photomicrographs of graphic intergrowth of bornite and chalcocite which is interpreted as replacement of bornite by chalcocite. Bornite(dark grey). Chalcocite(white). Gangue(black). Magnification X 275.

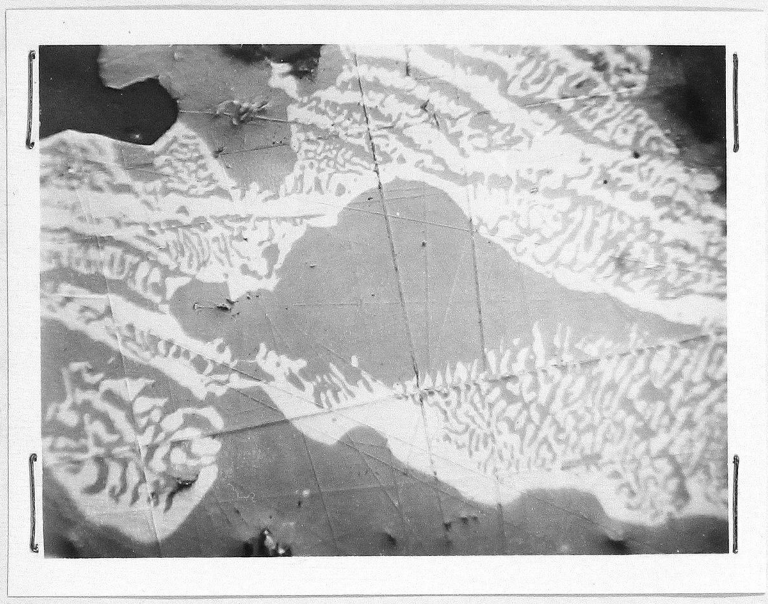


PLATE XV. FIG. I.

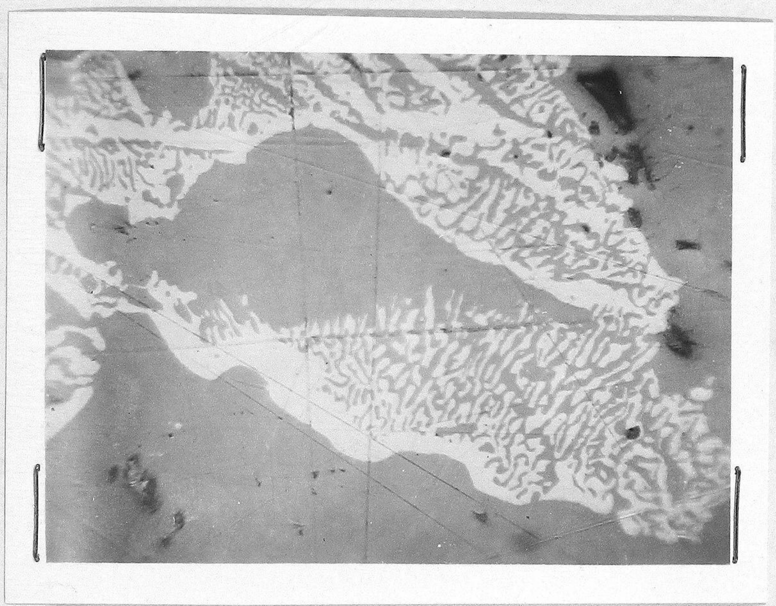


PLATE XV. FIG. 2.

(Plate XVI. Fig. I.) seems to be undoubted proof of replacement, and the fact that these veins extend from a rim of chalcocite(Plate XVI. Fig. 2.) would add further evidence.

The continuity of the white chalcocite along the fractures from the areas of intergrowth, to areas of rim replacement and traversing veinlets definetly establishes the fact that it is all one generation of chalcocite. A final indication of replacement is evidenced by the extremely minute micro-veinlets of chalcocite which in places traverse the lobes of bornite.

The last phase of the hypogene mineralization is represented by calcite veinlets which are found widespread throughout the ore. They are reticulate in form and are found cutting across all the ore minerals except those of supergene origin. These veinlets are important in that the supergene solutions used them as passageways by which they were enabled to penetrate the orebodies. The supergene minerals are directly associated with the calcite veinlets and the fractures. The fact that the calcite veinlets cut the bornite and chalcocite may be cited as further evidence for the hypogene origin of these sulphides.

The walls of the calcite veins in many places are distinctly parallel. This suggests that there was possibly a certain amount of fissuring later than the mineralization but prior to the introduction of calcite.

Supergene Enrichment:

In the Copper Mountain Mine supergene enrichment is not of very great importance. It has proceeded from the reticulating veinlets of calcite and the fractures. The simple sulphides of copper, namely covellite and chalcocite, have replaced the copper iron sulphides bornite and

PLATE XVI. FIG. I.

Camera lucida drawing showing a vein of hypogene chalcocite(Cc) cutting across bornite(B). The chalcocite also rims the bornite. Gangue(G). Magnification X 275.

PLATE XVI. FIG. 2.

Camera lucida drawing showing chalcocite replacing bornite by the characteristic rim pattern. Also blades of chalcocite in bornite and massive replacement of bornite by chalcocite. Hematite(H). Magnification X 275.

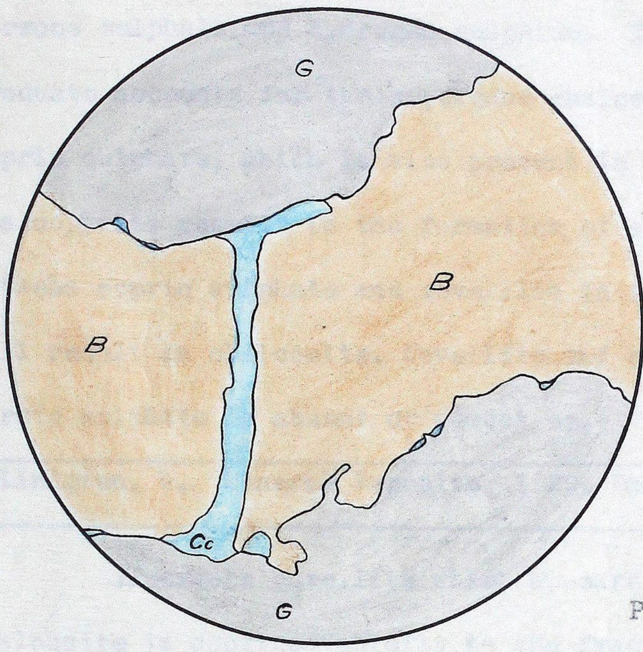


PLATE XVI. FIG. I.

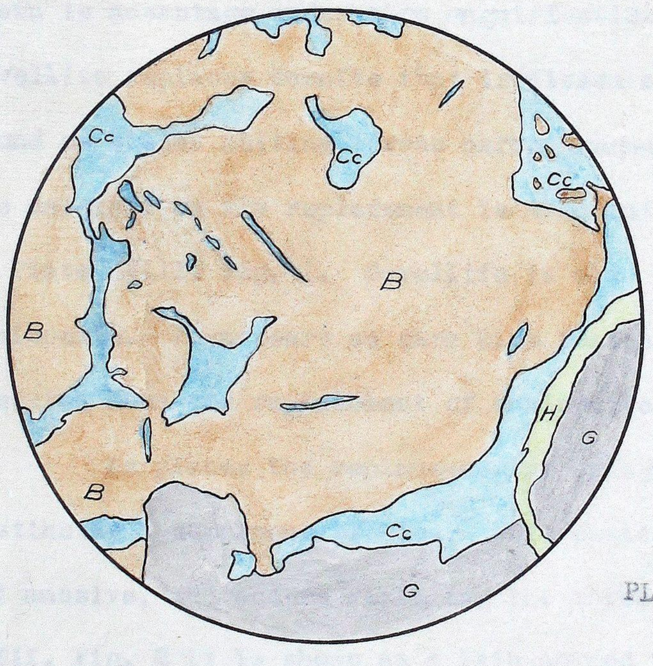


PLATE XVI. FIG. 2.

chalcopyrite.

The action of surface waters containing sulphuric acid on hypogene bornite will account for the formation of covellite, chalcocite, ferrous sulphate and hydrogen sulphide. The further reaction between these products accounts for the supergene chalcopyrite present. The action of cupric sulphate, which is also present in these waters, on primary chalcopyrite results in the formation of covellite. The further reaction between cupric sulphate and covellite in the presence of sulphuric acid will result in chalcocite. Covellite and chalcocite are precipitated after ferric sulphate is absent or almost so.#

Lindgren, W. Mineral Deposits, 1928. Page 943.

Supergene covellite which appears to be slightly older than the chalcocite is confined chiefly to the fractures. It replaces bornite and chalcopyrite marginally(Plate XVII. Fig. 1&2.). It is also found replacing disseminated bornite in scattered areas throughout the ore. It is only shown to advantage under high magnification. This is especially true where covellite replaces bornite that is disseminated. In several places it is found as blades cutting across narrow segments of bornite(Plate XX. Fig. 2). The marginal or rim replacement is the best defined and is well brought out in Plate XVIII. Fig. 1. Covellite is also found admixed with hypogene chalcocite. It appears as dark blue feathery aggregates suggesting the breaking down and replacement of chalcocite by covellite.

In places the replacement of hypogene sulphides by chalcocite is distinctly a supergene process. This chalcocite is bluish in color, is not massive, and occurs replacing the three hypogene sulphides. In Plate XVIII, Fig. 2 it is shown as a lath shaped veinlet cutting across chalcopyrite and bornite and also as a segregated lath in the bornite. It is

PLATE XVII. FIG. I.

Camera lucida drawing showing supergene covellite(Co) replacing bornite(B) and chalcopyrite(Cp). Gangue(G). Magnification X 275.

PLATE XVII. FIG. 2.

Camera lucida drawing showing supergene covellite(Co) replacing chalcopyrite(Cp). The covellite rims the chalcopyrite and it's association with calcite(C) is shown. Gangue(G).

Magnification X 550.

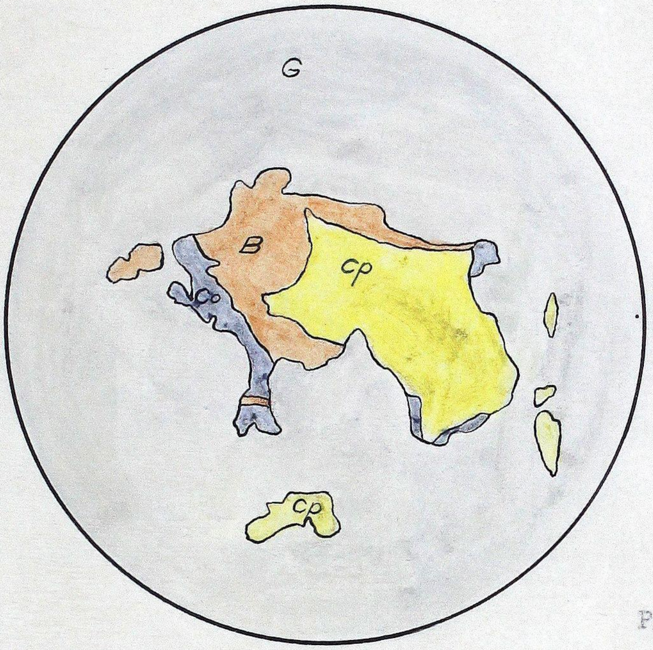


PLATE XVII. FIG. I.

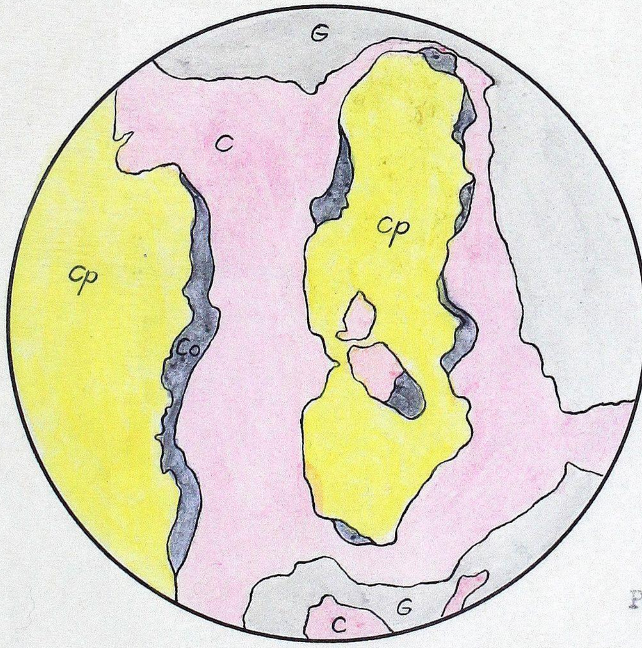


PLATE XVII. FIG. 2.

PLATE XVIII. FIG. I.

Camera lucida drawing showing covellite(blue) replacing bornite (brown) and chalcopyrite(yellow). Gangue(grey). Magnification X 275.

PLATE XVIII. FIG. 2.

Camera lucida drawing showing covellite (blue) replacing bornite. A lath of chalcocite(azure) cuts across bornite and chalcopyrite(Cp), and there is a segregated lath of supergene chalcocite in bornite. Magnification X 275.

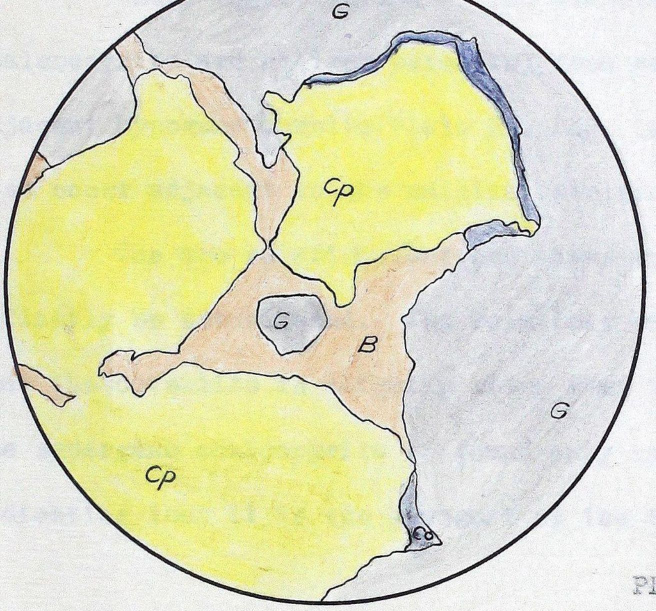


PLATE XVIII. FIG. I.

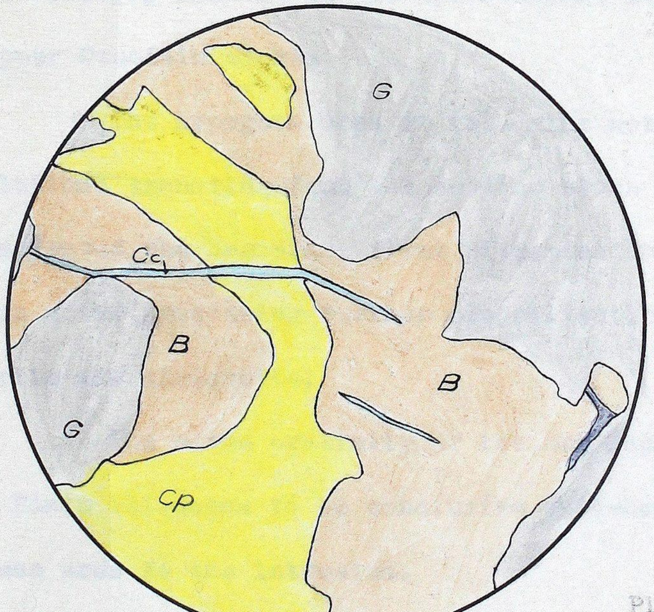


PLATE XVIII. FIG. 2.

confined chiefly to the fractures. The supergene blue chalcocite in certain places as very fine blades(Plate XIX. Fig. 2.) and feathery aggregates in the hypogene chalcocite and bornite.

Under magnification of 550 diameters, isolated blades of supergene chalcopyrite are noticed extending from reticulating calcite veinlets into adjacent hypogene bornite(Plate XX. Fig. I&2.). These blades of chalcopyrite also occur adjacent to the calcite veinlets but disassociated.

The age relations between these supergene minerals could not definetly be established. The relations that were observed however suggests that the covellite is slightly older than the chalcocite and chalcopyrite. The supergene chalcopyrite is found only in the largest fractures, probably indicating that it is the youngest of the three.

(f) Origin:

It is believed that the ore deposits of the Copper Mountain Mine are directly related to the hydrothermal stage of the intrusion of the Copper Mountain stock.

The hypogene ores at this mine were deposited by hot magmatic solutions emanating from the cooling stock magma. These hot solutions penetrated the breccias, first disseminating bornite and chalcopyrite,,and then after fracturing further mineralization consisting of bornite chalcopyrite and chalcocite.

The close proximity of the ore deposits to the stock as is shown in Plate VII seems to be conclusive evidence of the direct relationship of these ores to the intrusion.

The absence of quartz from the ores and the stock itself, and the presence of bornite and chalcopyrite in both adds further to the proof.

PLATE XIX. FIG. I.

Photomicrograph showing covellite(Co) replacing bornite(B) and chalcopyrite(Cp).
Magnification X 275.

PLATE XIX. FIG. 2.

Photomicrograph showing a fine lath-like veinlet of supergene chalcocite cutting across and replacing chalcopyrite.
Magnification X 275.

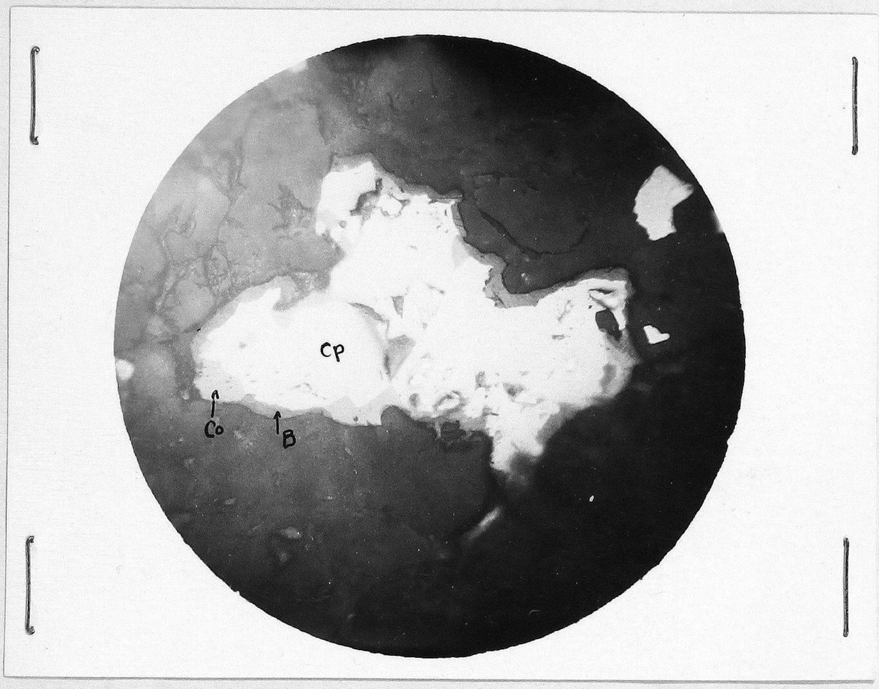


PLATE XIX. FIG. I.

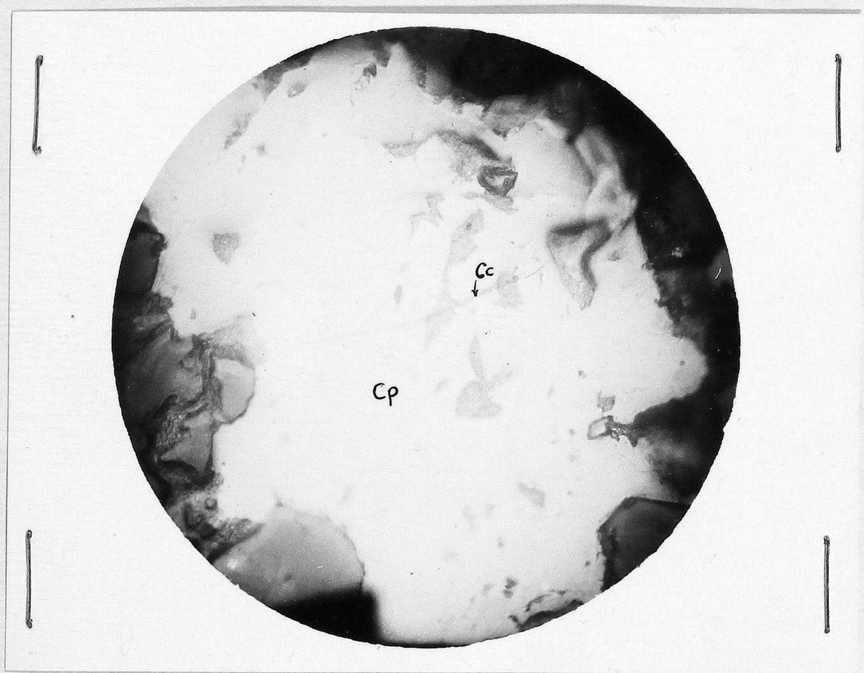


PLATE XIX. FIG. 2.

PLATE XX. FIG. I.

Camera lucida drawing showing blades of supergene chalcopyrite(Cp) replacing bornite(B). The relation between chalcopyrite and calcite(C) is shown. Magnification X 550.

PLATE XX. FIG. 2.

Camera lucida drawing showing blades of supergene chalcopyrite(Cp) in bornite(B). Covellite is shown replacing and cutting across bornite. Covellite(Co). Calcite(C). Magnification X 275.

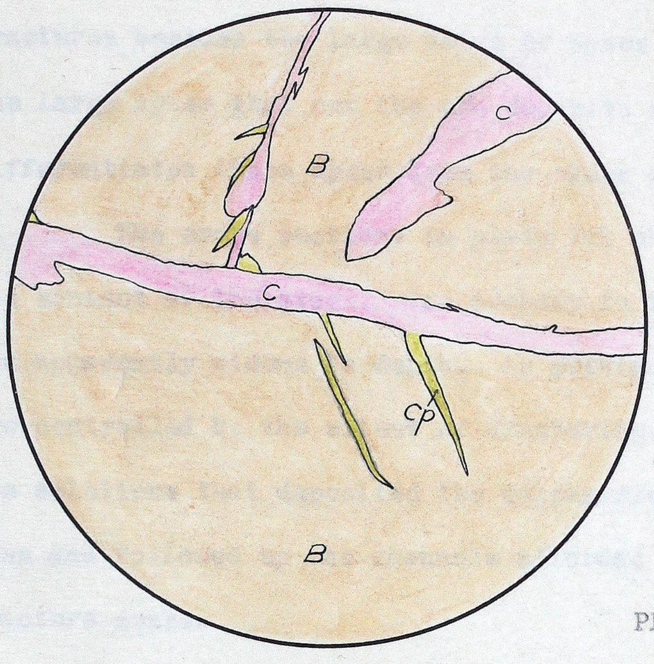


PLATE XX. FIG. I.

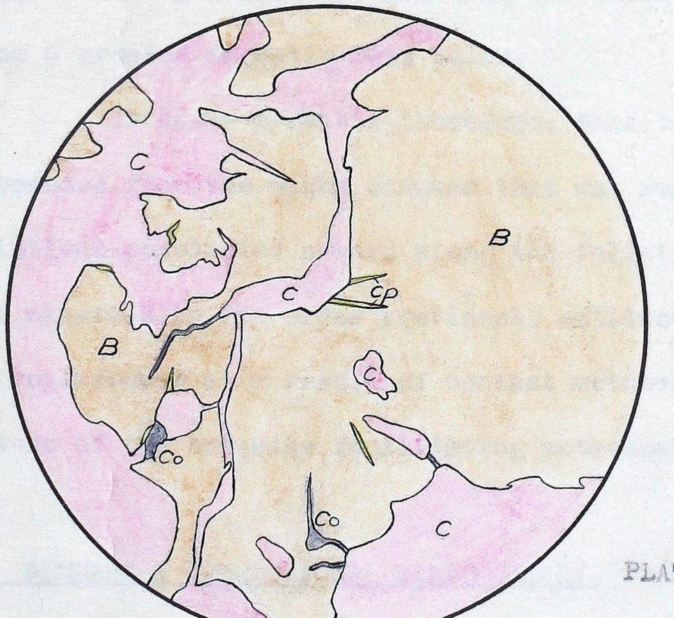


PLATE XX. FIG. 2.

Similarity in mineral composition lends further evidence to the genetic relationship between the orebodies and the intrusive. Pegmatitic material makes up the core of the stock and is found in many of the fractures besides the large veins or dykes in the vicinity of the deposit. The large dykes that cut the ore deposits contain quartz in places. This differentiates these dykes from the older rocks in mode of origin.

The cross sections in plate VII shows the orebodies paralleling the contact of the stock. One orebody is in direct contact with the stock and apparently widens in depth. As previously stated, these orebodies are controlled by the extent of fracturing. It would seem therefore , that the solutions that deposited the copper-rich minerals eminated from deep down and followed up the channels afforded by the foliation planes and the fracture zones.

The fact that the walls of the stock are vertical and it is ovoid to circular in plan, conforms with the definition of a true stock. This suggests the probability then that the stock was formed as a protuberence from a greater magmatic mass below.

It seems probable therefore, that the ore bearing solutions proceeded from the magma chamber that was responsible for the stock. These solutions penetrated upward along the foliations and fractures and deposited the minerals in the order previously outlined. The whole process is one of replacement as a result of contact metamorphism with the fractured nature of the breccias facilitating metasomatism.

V. SUMMARY & CONCLUSIONS: BIBLIOGRAPHY.

I. The Copper Mountain Mine is one of the three principal deposits of copper in British Columbia.

2. A resume is given of the topography and geology.

3. The deposit is of the epigenetic, contact metamorphic type, or in other words pyrometasomatic.

4. The source of the ores is believed to be the magma chamber from which the Copper Mountain stock originated.

5. Alteration consisting of biotitization and sericitization extends irregularly both in intensity and location from the stock contact outwards. Along with the biotitization the first period of mineralization took place, when the breccias of the Wolf Creek formation were mineralized to a certain extent.

6. The gangue material consists of the oxides magnetite, and hematite, the silicates epidote, and zoisite, along with apatite, orthoclase, albite, biotite, and calcite.

7. Fracturing and foliation as a result of stresses affected the Wolf Creek formation to an important extent adjacent to the stock.

8. Hypogene mineralization consists of an early and a late stage. The early stage previous to the fracturing and the late stage subsequent to it.

9. The late stage of hypogene mineralization which is the important one, consisted of the deposition in the fractures by ascending thermal solutions of bornite, chalcopyrite, and chalcocite in the order named.

IO. Calcite veinlets, reticulate in form, mark the end of the hypogene period and are important.

II. Supergene solutions have enriched the deposit to a certain extent by the deposition of covellite, chalcocite, and chalcopyrite.

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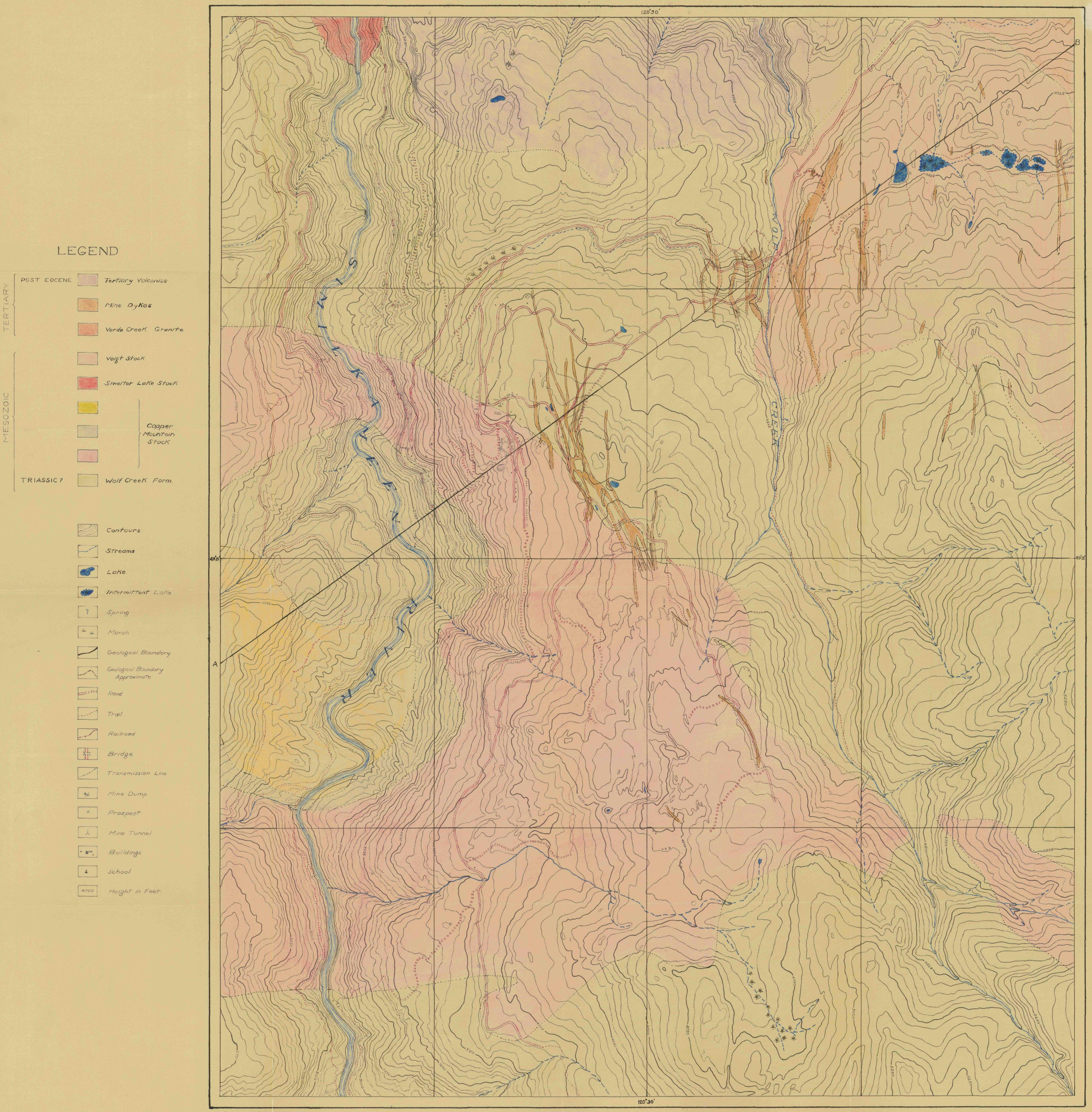

Geology by V. Dolmage, 1925, 1926
Topography from surveys by D. A. Nicols, 1922

Datum is Mean Sea Level

COPPER MOUNTAIN AREA

SIMILKAMEEN DISTRICT

BRITISH COLUMBIA

Scale, 1:12,000 or 1 inch to 1000 Feet

Feet: 1000 0 1000 2000 3000

Contour interval 50 Feet

APPROXIMATE MEAN DECLINATION, 1923

To accompany thesis by Harold M. Wright
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