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A MINERALOGRAPHIC EXAMINATION
OF SPECIMENS FROM
THE ROCHER DE BOULE MINE

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C O N T E N T S

Summary	Page	1
Introduction		2
The Rocher de Boule Mine		2
Specimens Examined		3
Mineral Determinations		4
Metallic-lustred Minerals		4
Gangue Minerals		6
Minerals Absent		8
Mutual Relations and Paragenesis		10
High Temperature Minerals		10
Medium Temperature Minerals		12
Paragenesis		13
Conclusions		14
Bibliography		15

I L L U S T R A T I O N S

Fig.1. Specimens and Contained Minerals	Page	9
Fig.2. Arsenopyrite, Chalcopyrite and Quartz.....		16
Fig.3. Chalcopyrite replacing Skutterudite.....		16
Fig.4. Marcasite pseudomorphous after Pyrite		16
Fig.5. Actinolite selectively replacing Chalcopyrite		17
Fig.6. Tennantite later than Sphalerite.....		17
Fig.7. Tennantite-Galena, mutual boundaries		17

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Summary

A suite of mineral specimens from the Rocher de Boule mine, near Hazelton, were examined by mineralographic means and found to contain copper, cobalt, molybdenum, lead, and zinc sulphides and arsenides. Chalcopyrite and arsenopyrite were the most abundant high temperature minerals, while sphalerite and tennantite-tetrahedrite were characteristic of the mesothermal assemblage. Two periods of mineralization were determined and a paragenetic sequence suggested.

Introduction

This report is the result of a detailed study of a suite of specimens from the Rocher de Boule mine undertaken during the winter session of 1950 as part of the regular course in mineralogy at the University of British Columbia. The author is indebted to Dr. H.V.Warren, Dr. R.M.Thompson and W.Poole for valuable instruction and assistance in mineral determinations. The various publications listed in the bibliography were drawn upon as required.

The mineral associations and the paragenesis suggested in the following pages were determined from a suite of nine specimens taken from three isolated parts of the mine, and cannot be considered representative of the mine as a whole. Several minerals not mentioned in previous reports were discovered, and some minerals known to be present at the mine were apparently absent in the specimens examined. An attempt has been made to correlate the results obtained with the paragenesis as determined by J.J.O'Neil in 1919.

The Rocher de Boule Mine

This property is located in the Hazelton sub-district of the Omineca mining division of the northeastern mineral survey district of British Columbia. The mine is on the south side of

the Rocher Deboule mountains, near the head of Juniper Creek, and extends from an elevation of 3900 feet at the creek to the top of the ridge at 5700 feet elevation. The adit of the main cross-cut tunnel is 4167 feet above sea level. In the vicinity of the mine, the mountain, an exposed granodiorite stock, is cut by five sub-parallel mineralized fissures, two of which contain high grade shoots of chalcopyrite ore. The wall rocks have been altered to chlorite and sericite, and the fissures have been filled with a quartz-hornblende gangue carrying an assemblage of high and medium-temperature minerals.

Two distinct types of commercial ore occur: the first, contained in No.4 vein, consists of chalcopyrite and auriferous arsenopyrite in a gangue of hornblende, actinolite and glassy quartz; the second, confined principally to vein No.2, comprises argentiferous tetrahedrite, sphalerite and galena interbanded with milky quartz. The Rocher de Boule mine operated from 1915 to 1918 and produced over $5\frac{1}{2}$ million pounds of copper, 63,000 ounces of silver, and 4000 ounces of gold. It closed in 1919 when the high-grade ore was exhausted. No attempt was made to recover any of the other metals in this complex ore.

Specimens Examined

The specimens studied were all obtained from the No.4 veins: three from the Cobalt Shoot; three from the dump at the 300-foot level; and three from the dump at the 500-foot level. Polished sections were prepared and examined under the microscope. The minerals were determined by a systematic series of tests, including color,

hardness (Talmage Scale), crystal habit, associations, anisotropism, etch reactions and microchemical reactions. Hand specimens were used as a check on microscopic determinations and, in two cases, X-ray powder photographs were made by R.M. Thompson. The specimens were also tested for radioactivity and fluorescence. When the minerals had all been determined, the polished sections were critically examined and analysed in an attempt to determine the paragenesis of the ore. The polished sections used, and the minerals determined in them, are shown in Figure 1.

Mineral Determinations

Metallic-Lustred Minerals

Molybdenite (MoS_2): This mineral occurred in curved laths and plates. It was light purple in color and had a hardness of B. It was strongly pleochroic in polarized light and, under crossed nicols, showed four extinctions with anisotropic colors from white, through violet, to black.

Arsenopyrite (FeAsS) In the hand specimen this mineral was crystalloblastic, with a few triangular facets and many elongated, cross-striated fragments. The polished section contained diamond-shaped sections, long euhedral prisms, and large irregular grains. These were white, had a hardness of F, and were strongly anisotropic, the colors ranging from yellow-orange to violet. They stained iridescent to grey with dilute nitric acid.

Loellengite (Fe_3As_4): Difficulty was experienced in distinguishing this mineral from Arsenopyrite, with which it was

invariably intergrown. The colors, hardness, anisotropic properties and etch reactions were similar, but it lacked crystal form and occurred in small, irregular, serrated grains, averaging about one-sixth the size of the arsenopyrite grains. After comparison with standard sections, careful observation under crossed nicols served to distinguish it from arsenopyrite. An X-ray powder analysis, made by R.M.Thompson, verified its presence.

Nickeliferous Skutterudite(Co,Ni)As₃: This mineral occurred in aggregates of small (less than 0.5 mm), sub-cubic to sub-triangular, equiaxed grains, enclosed by quartz or by chalcopyrite and quartz. It was white in color, had a hardness of F, and was isotropic, which distinguished it from Arsenopyrite and safflorite. Microchemical analyses revealed that it contained cobalt and arsenic, with minor nickel, but no iron. The relatively low percentage of nickel eliminated the nickel arsenides. It was distinguished from cobaltite by its color and by the fact that it stained light grey with concentrated nitric acid. Cobaltite is negative to all acids. (See Warren and Thompson, 1945).

Cobaltite (CoAsS): This mineral was sparingly present, consisting of a few roughly-cubical to rounded grains about 0.5 mm in diameter, scattered through the skutterudite or alone in quartz. It was pale pinkish-white in color, had a hardness of G, was isotropic, and resisted concentrated nitric acid. It was also verified by an X-ray photograph taken by R.M.Thompson.

Marcasite (FeS₂): This mineral occurred in only one specimen, with chalcopyrite and glassy quartz. It was in distinct euhedral crystals, partly pseudomorphous after pyrite. It was a very

pale brass yellow, had a hardness of F, and was slightly anisotropic. The color, anisotropism, and a slight brown stain with nitric acid distinguished it from pyrite.

Chalcopyrite (CuFeS_2): The chalcopyrite occurred in large and small formless masses and was the most abundant mineral in the specimens. It was distinguished by its bright brass-yellow color, its hardness of C, its slight anisotropism, and its greenish streak. It was not as sectile as gold.

Sphalerite (ZnS): In the hand specimen, this mineral displayed dodecahedral cleavage and an adamantine lustre. In the polished section it was dark grey, had a hardness of D, and showed its characteristic golden-yellow internal reflection.

Galena (PbS): The cubic cleavage, white color, softness and isotropism were distinctive for this mineral.

Tennantite-Tetrahedrite ($5\text{Cu}_2\text{S} \cdot 2\text{CuS} \cdot 2\text{As}_2\text{S}_3$ -- $5\text{Cu}_2\text{S} \cdot 2\text{CuS} \cdot 2\text{Sb}_2\text{S}_3$): This mineral occurred in fine-grained masses, replacing sphalerite and galena. It showed no crystal form. It had a distinct greenish-grey color adjacent to galena and a hardness of D. Positive etch reactions were obtained with nitric acid and potassium cyanide. Microchemical tests showed abundant arsenic and minor antimony, so the mineral in these specimens was closer to the tennantite end of this isomorphous series.

Gangue Minerals

Quartz: Quartz occurred in two forms in these specimens: The high temperature minerals were accompanied by large, glassy, closely-interlocked, twinned crystals, while the medium-temperature minerals were characterized by a finer-grained, milky white, banded

variety in subhedral aggregates.

Altered Hornblende: This was the main gangue mineral in the Chalcopyrite ore. It was largely altered to some form of fibrous chlorite unidentifiable in polished sections. Since it was probably derived from the granodiorite country rock, a more descriptive term would be "altered mafic minerals".

Feldspar: A very pale green, unaltered mineral with nearly 90-degree cleavage, one of which is basal, and a highly-vitreous lustre, occurred in the specimen containing the molybdenite. It had a hardness of about 6 and was probably an alk^aline feldspar. It was accompanied by altered hornblende.

Actinolite: This was a close-felted mass of short fibres, with a dark greenish-black color and vitreous lustre that formed the entire gangue in one specimen of chalcopyrite ore, which it had extensively replaced.

Sericite: This was developed on some of the sheared surfaces on the specimens containing the high temperature minerals. It was considered by O'Neill (1919) to be a pre-ore alteration product.

Calcite and Siderite: These minerals filled myriad small cracks in all the older minerals, but did not appear to replace any of them.

Erythrite: Pink cobalt bloom covered all exposed surfaces of the cobalt minerals, and was almost invariably accompanied by chalcopyrite. It did not form on the arsenopyrite or on chalcopyrite unaccompanied by cobalt minerals.

Minerals Absent

Gold: No free gold was discovered in any of the specimens, and microchemical tests of the arsenopyrite failed to reveal any indication of this element.

Silver: No silver minerals were discovered, and the tennantite-tetrahedrite was tested for silver without success.

Magnetite, Pyrite and Pyrrhotite: These minerals were reported by O'Neill to occur in this ore in minor amounts, but were not discovered in the specimens examined, although the marcasite indicated that pyrite was originally present.

Tungsten minerals: The specimens were all examined under the ultra-violet lamp but no scheelite was discovered. This test was made because scheelite occurs in the nearby Red Rose property in veins related to those in this mine.

Radioactive minerals: Since uranium-bearing minerals are frequently associated with cobalt, a radio-activity check was made on the following four specimens:

Normal count for 5 minutes		340 units
Specimen Co8	" " "	339 "
" B1	" " "	390 "
" B2	" " "	291 "
" A3	" " "	334 "

Specimen B1 contained molybdenite and feldspar, and the slightly higher count could easily be due to potassium in the latter.

No uranium minerals were visible.

<u>Section</u>	<u>From</u>	<u>Metallic Minerals</u>	<u>Gangue</u>
A1	500-Level	Sphalerite, Galena, Tennantite-Tetrahedrite	Milky Quartz
A2	" "	Arsenopyrite	Glassy Quartz
A3	" "	Tennantite-Tetrahedrite, Galena	Milky Quartz
B1	300-Level	Molybdenite	Hornblende, Feldspar, Glassy Quartz
B2	" "	Chalcopyrite, Arsenopyrite	Actinolite
B3	" "	Chalcopyrite	Altered Hornblende
B3A	" "	Marcasite, Chalcopyrite	Clear, amber Quartz, Altered Hornblende
Co3	Cobalt Shoot	Chalcopyrite	Glassy Quartz
Co7	" "	Arsenopyrite, Loellingite, Chalcopyrite	Glassy Quartz, Altered Hornblende, Sericite, Erythrite
Co8	" "	Skutterudite, Cobaltite, Chalcopyrite, Arsenopyrite	Glassy Quartz
Co8A	" "	Skutterudite, Cobaltite, Chalcopyrite, Arsenopyrite	Glassy Quartz

Figure 1. Specimens and Contained Minerals

Mutual Relations and Paragenesis

High Temperature Minerals

Molybdenite was found in only one specimen, taken from the dump on the 300 foot level. No other metallic-lustred minerals occurred with it, so no paragenetic relations could be determined. It was accompanied by a massive crystalline light-green feldspar, obviously different to that in normal granodiorite, and therefore probably of high-temperature replacement origin. Small residuals of altered mafic minerals were left in both the molybdenite and the feldspar, but no replacement criteria were observed. No quartz was present. The molybdenite and the feldspar were probably contemporary but later than the alteration of the granodiorite. They may possibly have preceded the silicification (see "Paragenesis")

In polished section Co7, the arsenopyrite-loellingite mass contained inclusions of euhedral glassy quartz, and was itself euhedral into altered hornblende. No definite veining relationships were seen, but the section strongly suggested that the arsenopyrite was selectively replacing the hornblende, and was later than the quartz. In the same section, chalcopyrite veined the arsenopyrite in a number of places and formed sharp boundaries with it, as well as appearing to follow the crystal boundaries of the quartz. This indicated that the chalcopyrite was later than both. See Figure 2. In the accompanying hand specimen, a thin veinlet, cutting the arsenopyrite and the gangue, contained chalcopyrite and erythrite, indicating that both the chalcopyrite and the cobalt

11

mineralization were later than the arsenopyrite.

The cobalt minerals were found only in section Co8. Small subhedral grains of skutterudite, cobaltite and arsenopyrite were scattered through glassy quartz and were apparently contemporaneous with it. The first two minerals also occurred in aggregates of fissured, rounded grains, partly or completely surrounded, and occasionally veined, by chalcopyrite. The latter was not badly fractured and appeared to have extensively replaced the cobalt minerals. It also appeared to have followed the crystal boundaries of the quartz but not to have replaced it. Since the veinlet cutting the arsenopyrite in section Co7 contained erythrite, the order of mineralization must have been quartz; arsenopyrite and loellingite; skutterudite and cobaltite; and chalcopyrite. See Figure 3.

Chalcopyrite occurred with three different gangue minerals. In specimen Co3, which was taken from a point near the cobalt shoot, the gangue was glassy quartz, and the chalcopyrite veined and replaced it. In specimen B3, from the 300-foot level, massive chalcopyrite occurred in a gangue of altered hornblende. No distinct replacement criteria were found. Fringing this ore was an area of strongly crystalline, twinned, clear, yellowish quartz and prismatic crystals of marcasite with well-developed polysynthetic twinning. Some of the marcasite was pseudomorphous after pyrite cubes, but most of it appeared to be primary. This suggested slow cooling conditions towards the close of the first mineralization period, with the formation of primary marcasite and replacement of earlier pyrite when the temperature dropped below 450 degrees centigrade.

This hypothesis would make the mascasite later than the chalcopyrite, and account for the crystal form of the quartz. See Figure 4.

A second period of high temperature mineralization was indicated by specimen B2, in which massive fibrous actinolite and euhedral arsenopyrite were developed and extensively replaced the chalcopyrite of the first mineralization . Arsenopyrite first veined the chalcopyrite and replaced it along the edges, with the formation of lath-shaped crystals. Actinolite then differentially replaced the chalcopyrite, forming radiating fan-like aggregations of acicular crystals, and isolating the arsenopyrite laths along the contact. Thin veinlets of actinolite extended into the chalcopyrite and fine, fibrous crystals radiated laterally from centres of crystallization along them. See Figure 5.

Medium Temperature Minerals

Sphalerite, galena, tennantite-tetrahedrite and quartz were present in two specimens taken from the 500-foot level of No.4 vein. In specimen A1, sphalerite and milky quartz were interbanded in approximately equal amounts. Smaller areas of galena occurred in the sphalerite and formed sharp mutual boundaries with it. Both were veined by later calcite-filled fractures and no replacement textures were observed, so it is assumed that they were formed at the same time. Small areas of tennantite-tetrahedrite, however, appeared to be selectively replacing sphalerite along the galena-sphalerite contact, since the calcite-filled veinlets ended at the tennantite, which was fractured in the opposite direction. See Figure 6. Thin, hair-like, microscopic whiskers of chalcopyrite, apparently related to the tennantite, extended outward from it

into the sphalerite.

Specimen A3 contained galena and tennantite-tetrahedrite in milky quartz. Here the galena appeared to have been almost completely replaced by tennantite but no indisputable replacement textures could be determined. Wedges of tennantite extended into individual grains of galena, which showed aligned cleavages on either side of the intrusion. Later, calcite-filled fractures cut both minerals. See Figure 7.

The paragenesis was tentatively determined to be: sphalerite, galena and quartz, followed by tennantite-tetrahedrite and, later still, by calcite.

Paragenesis

Based upon the foregoing examination, the following paragenesis is suggested:

First Mineralization

<u>Minerals</u>	<u>Evidence</u>
1. Granodiorite	J.J.O'Neill
2. Fissuring and alteration	J.J.O'Neill
3. Molybdenite and secondary feldspar	High temperature minerals later than the alteration. No quartz. Position uncertain.
4. Glassy quartz	High temperature form. Euhedral in arsenopyrite and loellingite.
5. Arsenopyrite and loellingite	Selectively replacing altered hornblende, but not quartz.
6. Skutterudite and cobaltite	Erythrite veining arsenopyrite.
7. Chalcopyrite	Veining skutterudite.
8. Marcasite	Pseudomorphous after pyrite. Slow cooling.

Second Mineralization

<u>Minerals</u>	<u>Evidence</u>
9. Arsenopyrite and actinolite	Veining and replacing chalcopyrite.
10. Sphalerite, galena and milky quartz.	Medium-temperature minerals and banding. Position of galena uncertain.
11. Tennantite-tetrahedrite	Selectively replacing sphalerite. Possibly replacing galena.
12. Calcite	Veining all earlier minerals.
13. Erythrite.	Oxidation product of cobalt minerals.

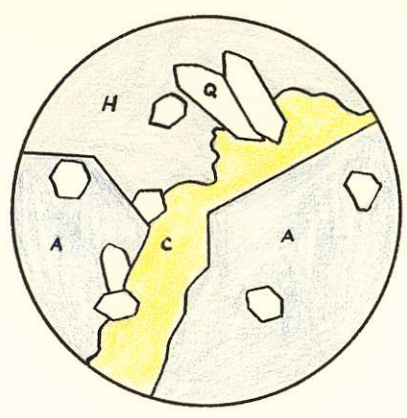
Conclusions.

The Rocher de Boule mine contains a complex assemblage of hypothermal and mesothermal minerals, apparently representing at least two stages of mineralization, each characterized by progressively cooling conditions, and both probably derived from the same source, since arsenopyrite occurred early in each sequence. The suite examined contained loellingite, skutterudite and cobaltite, minerals not mentioned by previous investigators, but was deficient in magnetite, pyrite and pyrrhotite, which are known to be present at the mine. Gold, silver, tungsten and uranium were also apparently absent from these specimens.

Mineralographic techniques, involving the use of polished sections, the polarizing microscope, and microchemical tests, readily determine most of the ore minerals. Some closely related species, however, can be differentiated only by careful comparative tests combined with considerable practise. Microscopic examination provides one of the most suitable means of determining the paragenesis of ores from their textures.

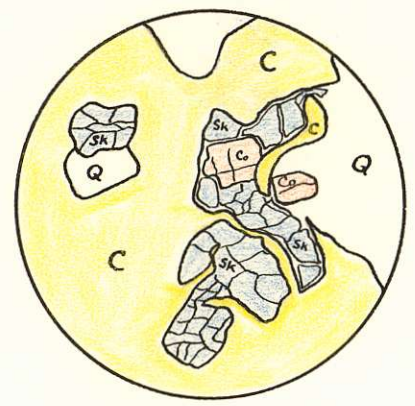
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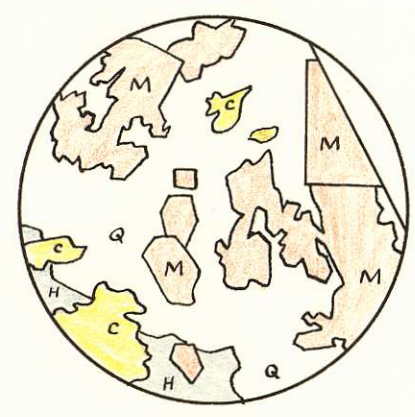
- A Arsenopyrite
- C Chalcopyrite
- Q Quartz
- H Hornblende

Fig.2. Arsenopyrite, Chalcopyrite and Quartz. X25



- Sk Skutterudite
- Co Cobaltite
- C Chalcopyrite
- Q Quartz

Fig.3. Chalcopyrite replacing Skutterudite. X10



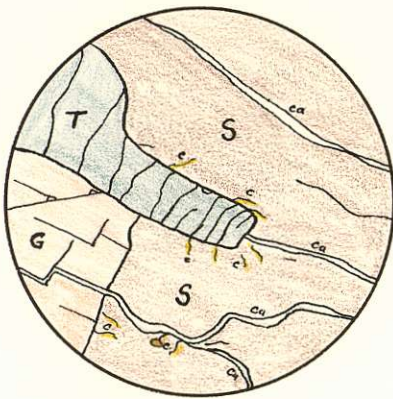
- M Marcasite
- C Chalcopyrite
- H Hornblende
- Q Quartz

Fig.4. Marcasite pseudomorphous after Pyrite. X20



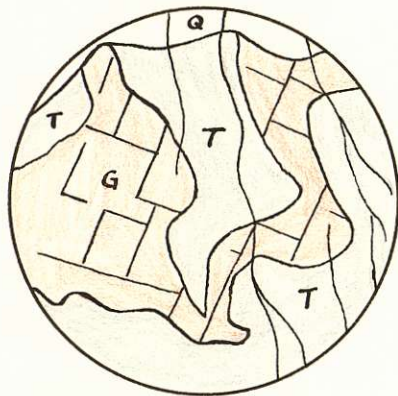
C Chalcopyrite
 A Arsenopyrite
 Act Actinolite

Fig.5. Actinolite selectively replacing Chalcopyrite. X20



S Sphalerite
 G Galena
 T Tennantite
 C Chalcopyrite
 Ca Calcite

Fig.6. Tennantite later than Sphalerite. X25



T Tennantite
 G Galena
 Q Quartz

Fig.7. Tennantite-Galena, mutual boundaries. X20