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MINERALOGY OF ORE FROM WINDPASS MINE

Submitted for credit in Geology 9

by

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Geological
Engineering

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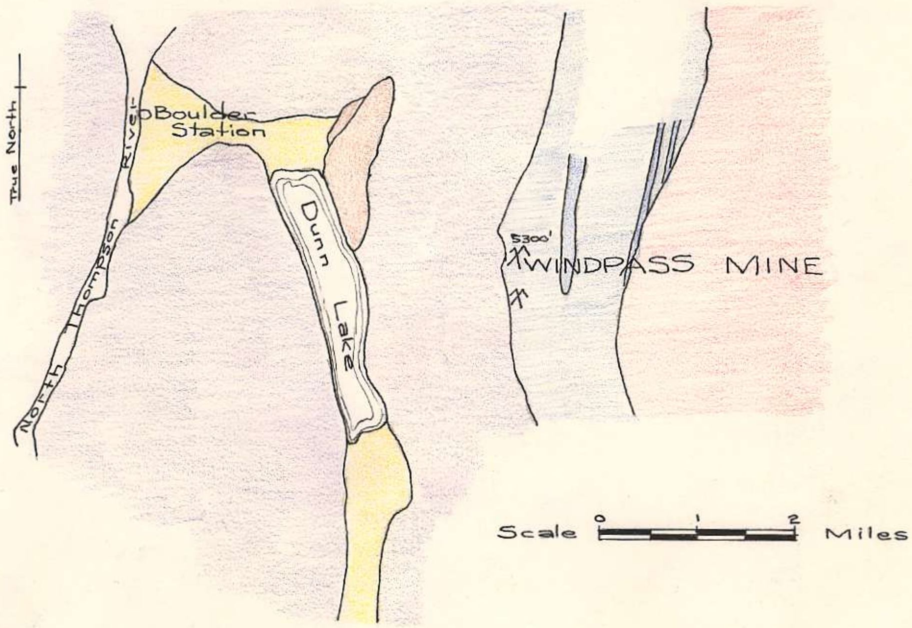
FOREWORD

The writer wishes to thank Dr. H. V. Warren, for his interest and critical suggestions, in examining this ore. Also he would like to thank Miss NormaKing for her expert assistance in determining the bismuth minerals.

MINERALOGY OF ORE FROM THE WINDPASS MINE, BOULDER, B. C.

Windpass mine is located approximately $3\frac{1}{2}$ miles east of Boulder station on the Canadian National Railway. The station is on the North Thompson River and is about 79 miles north of Kamloops, B. C. The map shows the exact position of the mine with respect to Boulder Station.

GEOLOGICAL MAP



GEOLOGICAL TIME TABLE

Recent	River gravel, sand, silt
Eocene	Chu Chua formation
Jurassic	Baldie biotite granodiorite and granite
	Micropegmatite - pyroxenite sills
Paleozoic or Pre-Cambrian	Fennell formation (greenstone sills and pillow lava)
	Badger Creek formation (micaceous quartzite, quartz slate, biotite schist, hornblende schist, dolomite)

The mine was discovered in 1916 and, by the time Dr. Uglow examined it in 1920, enough work had been done to reveal 100 ft. of an east-westerly striking quartz vein with a northerly dip, varying from 35° to 80°. The vein was characterized by pinches and swells both horizontally and vertically. This, it might be added, is a characteristic of hypothermal veins in the pre-Cambrian shield. The vein, as indicated above, varies from a few inches to 36 inches, averaging possibly 15 to 16 inches. High temperature minerals are abundant, particularly bluish-grey lodestone. Gold is scattered, apparently at random, throughout the deposit, occuring plainly in lodestone and quartz. Free gold could be panned from almost any section of the vein.

Subsequent development during the following decade, with attempted, though unsuccessful, mining, revealed that the vein continued at depth but was difficult to locate due to faulting.

In 1933 a 50-ton mill was constructed when development work assured sufficient tonnage for a few years. The complex faulting pattern was later solved and the mine operated successfully until the close of 1939.

The country rock is the upper pegmatite facies of the micropegmatite pyroxenite sill which trends in a north-south direction just east of the boundary of the Fennell Formation. Granite of the Baldie batholith outcrop 1¼ miles to the east and since the contact with the micropegmatite sill is dipping westerly, the granite actually may not be far below the deposit. The hydrothermal solutions that formed the deposit are thought to have originated in the granite magma.

MICROSCOPIC STUDY OF POLISHED SECTIONS

Magnetite, chalcopyrite, pyrrhotite, pyrite, sphalerite, bismuthinite, bismuth, possibly some telluride, gold, quartz, calcite and limonite have been seen in the polished sections under the microscope.

The gold, though later, apparently had a marked affinity for the pyrrhotite as a host mineral, though usually in association with bismuth and bismuthinite. Solutions carrying bismuth and gold attained access to the pyrohotite presumably by extensive fracturing that preceded this valuable deposition of gold. Possibly this fracturing was extensive enough to have excited the main ore-forming solutions to come off by partly releasing the confining rock pressure. Carbonate magmatic waters marked the end phase of this gold-bismuth bearing-solution activity. That this fracturing was intense is little doubted, for most specimens show a heterogenous succession of veined materials. The gold also occurs free, filling cracks in quartz, and invariably associated closely with bismuth minerals. The smallest size of gold particle seen was .006 mm or 6 microns in diameter. It is doubted whether gold of this size is recoverable and it was noticed that fine gold was abundant as is seen in plate 8.

Gold could be seen with the naked eye in several of the polished sections, measuring up to 0.5 mm. in diameter. Where gold occurred abundantly the values ranged from several ounces up to 145 ounces of gold to the ton for any appreciable ore shoot (cf. Dr. Wm. Smitheringale). Abundant gold invariably meant abundant bismuth minerals.

MAGNETITE, Fe $(Fe\ O_2)2$

The most noticeable feature of the magnetite studied, was the great extent to which it had been fractured and mineralized. The openings formed were later filled with sulphides, bismuth, bismuthinite, quartz or calcite.

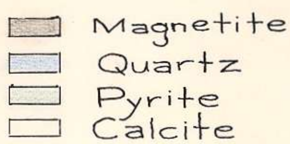
A large part of the magnetite was coarse grained. The average grain was 0.25 mm in diameter. This coarser magnetite was believed to be a second generation of magnetite. It is suggested that the coarse grained magnetite was more amenable to fracturing than the first generation of magnetite, which was fine grained.

It was necessary for the writer to prove that the powder was magnetic before he could be assured that he was dealing with magnetite. The fracturing has isolated so many small grains of magnetite, and this, together with the large amounts of calcite present made the apparent hardness of the mineral very deceptive. The magnetite was negative to all etch reactions.

Plate 1, from polished section, W 6, shows the relation of the chief gangue minerals, more or less, to the massive magnetite. The quartz is seen filling fractures in the magnetite as well as attempting to replace it along one of the contacts. Pyrite presumably was precipitated from solutions early during this siliceous deposition though not abundantly. It was later slightly replaced by quartz, from possibly, not so siliceous or acid polutions. Calcite came in later, probably due to a slight reopening of the earlier filled fissures.

PLATE 1.

268 X

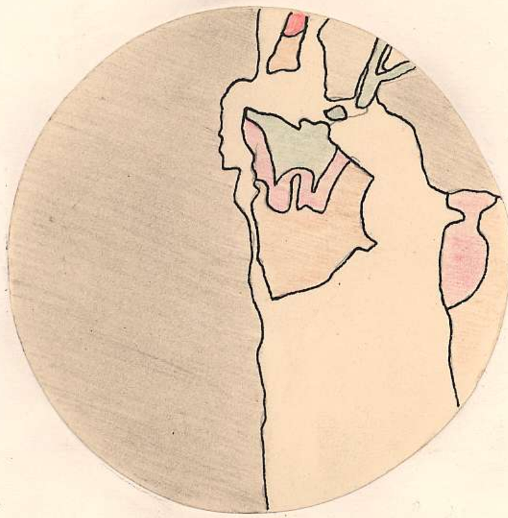


It replaced quartz and definitely corroded and ate away the majority of the pyrite which though originally small in quantity, now disappeared almost entirely.

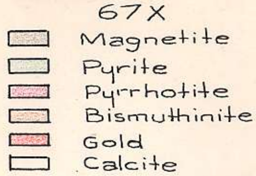
Other minerals found in magnetite can be examined in polished section W 5, represented here by plate 2.

The usual fracture is present containing corroded pyrite. Pyrite here apparently was attacked by less acid solutions carrying pyrrhotite which replaced it, to at least a marked extent. Bismuthinite depositing from a later series of solutions repeated the cycle of replacement on the pyrrhotite, which is characteristic of this deposit.

PLATE 2.



67X



The writer believes that the solutions carrying the bismuthinite were closely related or are the same solutions that carried the gold. That these solutions were alkaline is further postulated owing to the persistant association of bismuthinite, calcite and gold.

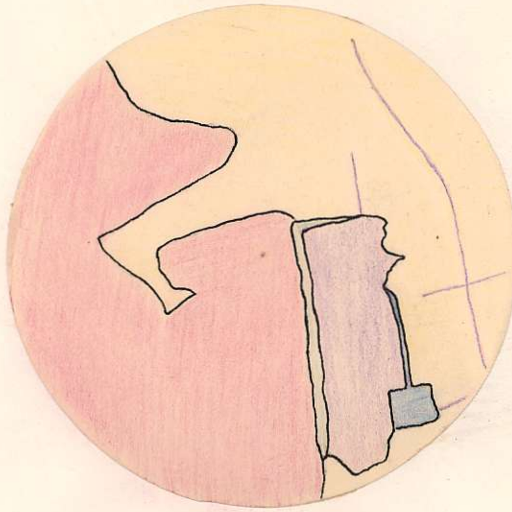
Thus it can be said that the early magnetite, when it has been later fractured and where it has lain in the path of later solutions of an auriferous bismuth character, is usually valuable ore. Most of the gold found in the magnetite was reasonably free and large enough to be recovered by tables.

PYRRHOTITE, $Fe_x S_{x+1}$

This is another mineral characterized by frequently abundant fracturing, insipient in the hand specimen but very noticeable in the polished section. The large majority of fine fractures are unfilled with any vein mineral suggesting gradual but intense post-mineral movement of the ore-body. This feature was brought out in the polishing, as these cracks were less resistant to the abrasive, consequently the polishing developed distinct profiles. The coarse grained pyrrhotite, brownish cream in reflected light, was easily recognized in all cases by its softness and tendency towards chemical inertness. The KOH reaction was very slow. The pyrrhotite contained no nickel. The powder was magnetic.

This mineral, as can be seen in polished section W 7, represented by Plate 3, is closely associated with chalcopyrite. Pyrrhotite can be seen cutting the chalcopyrite in small veinlets in W 7, though that feature is not expressed in Plate 3. From the plate a suggestion of the lateness of the pyrrhotite in this instance is obtained, and it is noteworthy to observe that by far the majority of inclusions are of chalcopyrite in pyrrhotite. This suggests that, at a certain stage, the solutions were richer in iron, possibly from the dissolving of some of the early magnetite, than in copper, and that the excess iron tended to precipitate out, metasomatically replacing the copper. The period of deposition of the pyrrhotite would be of the same metallogenetic age as the chalcopyrite, because they are so intimately associated with one another, and in some cases seen, absolutely defying interpretation as to separate paragenesis. Pyrite was frequently seen in veinlets cutting both pyrrhotite and chalcopyrite.

PLATE 3



353 X

In plate 3 it is seen developing along the contact of the latter two minerals. It is noticed that the crystal cast is still preserved by limonite mostly, and in itself, indicating a tendency for the pyrite to replace chalcopyrite in the presence of pyrrhotite. Another case of copper being driven into solution by iron. Note also that the solutions have finally become richer in sulphur than previous solutions.

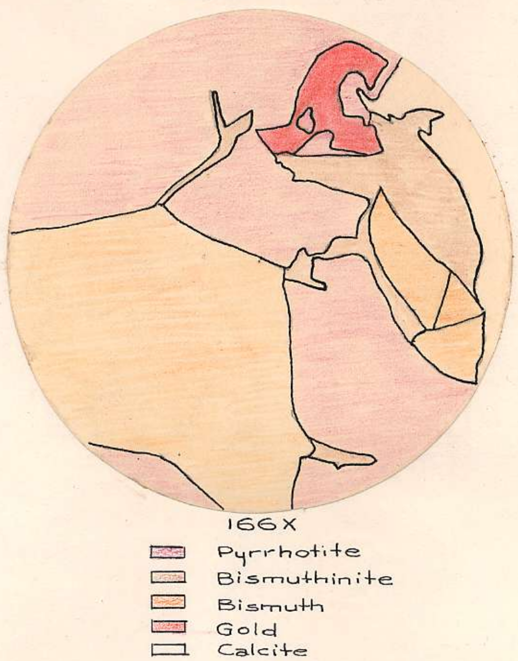
Pyrite is not abundant, as has been formerly suggested under the heading MAGNETITE, so this may mean that sulphur is not abundant. If so, this should be noted as a characteristic of the deposit.

Sphalerite is seen growing along the contact of the old pyrite cube and also replacing the pyrite and chalcopyrite. Zinc must have been a, more or less, minor constituent in the hydrothermal solutions or else there was not enough sulphur present to combine with it, for the writer has not seen much zinc blende in his specimens.

Pyrrhotite, when extensively fractured and later attacked by probably alkaline solutions, became an extensive depositing zone for the bismuth minerals. Plate 4, from polished section W 5, shows irregularily fractured pyrrhotite in association with bismuthinite, bismuth, calcite and gold. Bismuthinite evidently was the first bismuth mineral to deposit; later native bismuth came in replacing the bismuthinite but it is questionable if the bismuth replaced any of the pyrrhotite. Native bismuth is further evidence of the tendency toward a deficiency of sulphur in the magmatic waters. At present the evidence would indicate that the first solutions were sulphur-poor depositing magnetite, and then pyrrhotite and chalcopyrite. Later the solutions became enriched in sulphur enough to barely precipitate pyrite, sphalerite and finally bismuthinite in relatively small quantities, though locally in cases, these minerals are well developed. Finally with all the sulphur gone, the solution deposited bismuth, gold and calcite.

Gold is seen in plate 4 to replace pyrrhotite but in close association with the bismuth minerals. The piece of gold is o.115 mm in total length and is relatively large for this type of occurrence. Calcite, as a final filling, making the end of the deposition, is present.

PLATE 4

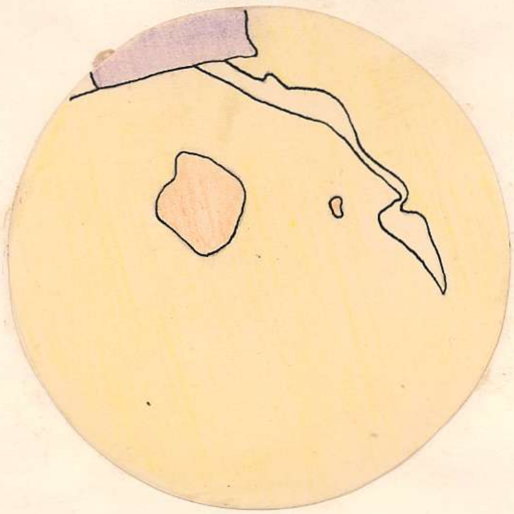


CHALCOPYRITE, $CuFeS_2$

The relation of chalcopyrite to pyrrhotite and pyrite has been discussed. It can be further noted here that the chalcopyrite also has characteristic post-mineral fractures shown in plate 3 as discontinuous bands of limonite running through the copper mineral. Weathering products evidently were deposited along the most minute cracks, but proferably in the chalcopyrite because they were not seen in that fashion in the pyrrhotite. No malachite or copper oxide was observed, so apparently the chalcopyrite was not attacked in this specimen by weathering agencies.

In plate 5, from W7, bismuth can be seen as two islands in the chalcopyrite. The writer believes this to be a case of impregation of bismuth in chalcopyrite; the nature of the bismuth-bearing solutions is strongly suggested by the presence of the stringer of calcite.

PLATE 5



67 X

Chalcopyrite
Bismuth
Calcite
Limonite

The chalcopyrite examined was weakly anisodropic and revealed friable characteristics when scratched. It was negative to reagents.

PYRITE FeS_2

Pyrite is seen cutting magnetite, though between the action of later replacement and ozidation it is usually left as little islands in the fractures. It also cuts pyrrhotite and chalcopyrite showing a definite tendency to replace the latter. The solutions were presumably sulphur - rich at the time and the iron may have come from the solution of earlier magnetite.

SPHALERITE (ZnS)

Sphalerite was distinguished by its medium softness, battleship grey color and internal red reflection. In the polished section it occurred in too small amounts to test chemically without destroying the evidence, but it was determined from the hand speciman. It was characteristically negative to reagents.

As earlier postulated, the deposition of the zinc from solution is supposed to represent a time when the solutions became barely enriched in sulphur enough to precipitate pyrite, and a little later, sphalerite. Its period of deposition was not long and it is not abundant.

BISMUTHINITE (Bi_2S_3)

In the sections studied, this mineral was very abundant, varying in size from small specks 0.1 mm. in diameter up to pieces that measured 5 mm. in diameter. It occurred as vein-filling and also as impregations in the quartz. Wherever the bismuthinite was well developed the quartz was well fractured. Under reflected light it was galena white, showing pitted surface due to one perfect cleavage being chipped in the polishing. Optically anisotropic with polarization colors varying from light grey to characteristic deep Prussian blue.

Plate 6, from section W 1, shows two very soft minerals; bismuth replacing bismuthinite. The bismuthinite is fairly coarse grained, in cases up to 2 mm. in diameter, but around contacts it is usually of a fine texture. Typical semi-spindleshaped twinning is usually developed to some extent.

PLATE 6

166 X

Bismuthinite
Bismuth

Wherever bismuthinite occurred, gold was usually nearby in the specimen. The following etch reactions were noted for bismuthinite:

HNO_3	HCl	KCN	$FeCl_3$	KOH	$HgCl_2$
+ tarnish light	—	—	—	—	—

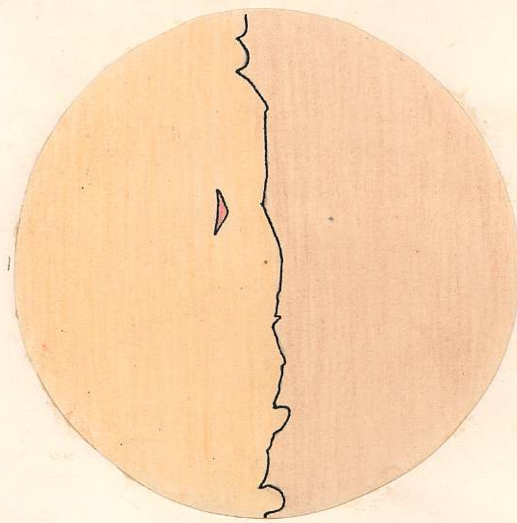
BISMUTH , Bi

Bismuth was found usually in contact with bismuthinite, and a difference could be detected in hardness, the bismuth being the softer of the two. The native metal has a pinkish hue to is bright, creamy color, and a distinct metallic luster. In this occurrence it is not strongly anisotropic, as claimed by Short, but varies from pinkish yellow to a peculiar, distinctive, pale violet. In W 5, typical twinned bismuth was examined. The following etch tests were considered correct.

HNO_3	HCl	KCN	FECl	KOH	$HgCl_2$
+	+	−	+	−	?

Plate 7, from W 1, shows possibly exsolution of gold from bismuth.

PLATE 7



67X

It is difficult to say whether the bulk of the gold came with the bismuth or bismuthinite; on the other hand, it might have been contemporaneous with both. It is definitely associated with both, but more so, statistically, with the bismuthinite.

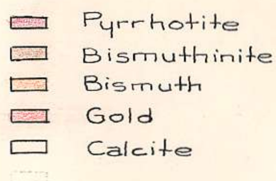
Bismuth is definitely a low temperature mineral having been deposited from solutions at less than 250 C.

GOLD Au

Plate 8, from W 5, shows a remarkable development of gold in pyrrhotite but under the genetic influence, presumably, of bismuth and bismuthinite.

PLATE 8

166 X



Gold also occurs in the bismuthinite and it is seen that very little bismuth is present. The smallest gold particle was 6 microns in diameter.

The most distinquishing test for gold was the application of KCN to the mineral, to give a tarnish.

Free gold was found in the magnetite, in sulphides, chiefly pyrrhotite, and in fractures in quartz; always, however, closely associated with bismuth minerals.

TELLURIDE

Microchemical tests for tellurium were persistantly responsive in several specimens. One section displayed a mineral in close association with bismuthinite and bismuth, which gave the following etch results.

HNO_3	HCl	KCN	FeCl	KOH	HgCl
+	−	−	+	−	?

The development of this mineral was destroyed on further polishing, prohibiting the writer to make an accurate drawing of this mineral's contact with bismuth and bismuthinite. This unknown mineral is possibly tetradymite, $Bi_2(Te,S)_3$ or joesite, (Te, Se)S.

MEGASCOPIC EXAMINATION OF ORE SPECIMENS

MAGNETITE

Evidence of high temperature origin of the magnetite was seen in specimen No.3414. It was composed of massive, medium grained, acid felspar with some hornblende, containing disseminated magnetite crystals. The presence of felspar and hornblende suggest high temperature deposition, whereas the magnetic impregnation may be evidence of pneumatolytic action. The felspar was later fractured with the introduction of bismuth minerals and gold.

Magnetite quite possibly, was of two generations. Specimen No.3410 shows cryptocrystalline magnetite cut by small lenses up to 5 mm. long, of coarsely crystalline magnetite. Blebs of pyrrhotite and chalcopyrite accompanied this second period of magnetite deposition. A possible explanation for the two generations was, that during the early stages of deposition, the wall rock was cool and unheated, thus inhibiting the growth of large crystals of magnetite. Later on, however, the walls became heated due to the passage of superheated solutions, thereby allowing coarsely crystalline magnetite to develop. In this specimen some chalcopyrite was seen replacing the coarse magnetite along parting planes. This evidently represents the copper-rich period of the hydrothermal solutions. There is a possibility that while pyrrhotite was replacing copper at greater depths, thus enriching the solutions in copper, chalcopyrite was replacing magnetite higher in the fissure.

Magnetite in specimen No.3403 contained unsupported inclusions of a diorite-like rock, probably a facies of micropegmatite. This shows the intense replacing action of solutions on the country rock. Free gold and chalcopyrite were seen, as well as a veinlet of quartz that cut across the specimen. The country rock is also cut by stringers of magnetite, as in specimen No.3413. Evidently the initial solutions had outlet through reasonably fractured ground when they came off from the magma.

PYRRHOTITE

It is thought that the pyrrhotite was the second metallic mineral to deposit in the veins. Quartz presumably began deposition during the period of magnetite deposition and continued long after the magnetite period was over.

Massive coarse grained pyrrhotite can be seen in specimen No.3405 with unsupported nuclei of blue grey to white quartz. That some of this quartz might have been β quartz, is suggested. The pyrrhotite is cut by irregular masses and stringers of chalcopyrite and also some later pyrite.

CHALCOPYRITE, $CuFeS_2$

Coarsely crystalline chalcopyrite cuts magnetite in Specimen No.3416 and definitely is later than pyrrhotite as seen in specimen No.3408. Though in this latter case, some pyrrhotite was deposited contemporaneous with the chalcopyrite. Notable though not unusual is the presence of two generations of quartz in No.3408. The earlier generation of quartz in veined by magnetite, whereas the later quartz cuts through the chalcopyrite. Flakes of a silvery white, metallic mineral with a pinkish hue were seen and thought to be bismuth. These flakes were lying along tight fractures in the quartz.

Sphalerite was seen in specimen No.3406 cutting chalcopyrite but apparently occurring only sparsely.

PROPOSED PARAGENESIS

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