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Report of Microscopic Examination of Ore from Hedley, B. C.

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by

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Description of Material Studied

In all six samples of ore were submitted by W.C. Douglas, Kelowna Exploration Co., accompanied by descriptions and assays.

A polished section, typical of each type of ore, was prepared and studied. A detailed description of each follows.

Sample #1

"Arsenopyrite ore from 4½ level, usually high grade, assay 2.28 ozs. per ton."

Megascopic

Section included one piece of massive arsenopyrite and one piece of gangue in contact with massive arsenopyrite.

Microscopic

Minerals identified:

Arsenopyrite	Calcite
Lollingite	Garnet
Cobaltite (?)	Epidote
Unknown Grey Mineral	Other silicates
Pyrrhotite	
Gold	

Arsenopyrite (FeAsS). Predominantly anhedral and massive, although developing crystal form in a few cases against gangue minerals. Between crossed nicols exhibits a coarsely crystalline nature, with tiny inclusions of calcite and silicates tending to be arranged

Plate 1

Unreplaced fragment of epidote lying along a crystal boundary in arsenopyrite, containing a bleb of pyrrhotite. Mag. x 800

Plate 2

Lollingite (light blue) and arsenopyrite (light grey). Showing blebs of pyrrhotite (brown), and the unknown grey mineral (darker grey with rough surface) replacing arsenopyrite. Gangue material is black. Mag. x 800 along crystal margins (Plate 1), as well as being scattered erratically through the mineral.

A little arsenopyrite is found in a rather finely disseminated form, occurring as anhedral crystals in silicates, close to the margins of the massive variety.

<u>Lollingite</u> ($FeAs_2$). Occurs as rare rounded blebs and inclusions within arsenopyrite. (Plate 2).

Observed properties:

Color - close to FeAsS but with a slightly more bluish cast.

Hardness - relief slightly lower than FeAsS.

Crossed Nicols - strongly anisotropic. 180° extinction.

Etch Reactions - HNO_3 stains surface brown, fumes tarnish - reaction less violent than upon FeAsS.
Other reagents negative.

Microchemical - impossible to obtain material uncontaminated by FeAsS. A test run on a contaminated sample yielded only Fe, As, and an indefinite reaction for sulphur, probably attributable to FeAsS.

A polished section of lollingite, prepared for comparison purposes, exhibited identical properties to the above, except for the absence of sulphur from microchemical tests.

<u>Cobaltite</u> (CoAsS) (?) Noted only under 1000 magnification, is rare, and occurs as tiny inclusions in arsenopyrite. In one place (Plate 4) encloses "islands" of pyrrhotite, in another (Plate 3) is found surrounded by arsenopyrite.

Color - light pinkish to violet grey.

Hardness - relief slightly above FeAsS.

Plate 3

Arsenopyrite, showing cobaltite(?) (violet) and pyrrhotite (brown). Note garnet in centre of arsenopyrite, also two tiny specks of gold. Gangue is black. Mag. x 1000

Plate 4

Arsenopyrite and cobaltite(?) (violet). Note islands of pyrrhotite (brown) in the cobaltite. The white material is a very thin coating of calcite over arsenopyrite. Gangue is black.
Mag. x 1000

Crossed Nicols - isotropic to faintly anisotropic.

Etch Reactions - HNO_3 doubtfully positive.

Other reagents negative.

Microchemical - a sample of arsenopyrite containing a bleb of this mineral yielded, in addition to Fe, As, and S, a weak but definite test for Co.

Quoting Camsell[1]

1. Geology and Ore Deposits of Hedley Mining District - Mem. 2, Geol. Sur. Can., 1910, p.138.

"The presence of cobalt was also suspected in combination with the arsenopyrite, making the mineral species danaite. But it has not been actually determined as such though the occurrence of hydrous arsenate - erythrite - on the outcrop of the Nickel Plate Ore body lends weight to this suspicion."

A series of microchemical tests were run on pure arsenopyrite, with negative results for Co in every case. Since under the conditions of the test a percentage as low as 0.3% Co in the arsenopyrite would have been detected, danaite (FeAsS with 3-9% Co replacing Fe) would seem to be absent. The presence of cobalt is probably attributable to cobaltite or a closely allied mineral.

Unknown Grey Mineral. Noted in only one place (Plate 2).

Color - sooty grey - variable color from light to medium grey on rotation in plane polarized light.

Hardness - relief below arsenopyrite or lollingite.

Crossed nicols - highly anisotropic - 90° extinction.

Etch Reactions - darkened by HNO_3.

Other reagents not applied.

Microchemical - impossible.

<u>Pyrrhotite.</u> Occurs disseminated through the gangue between crystal boundaries of, and replacing, silicates. In only a few places contacts arsenopyrite. Where this is the case blebs of pyrrhotite occur in arsenopyrite near the contact. (See plates 1, 2, 3, & 4.)

Neither chalcopyrite nor sphalerite were present in the section examined.

<u>Gold.</u> Numerous tiny inclusions of gold (from 7 microns down to the limit of microscopic resolution) are distributed erratically throughout the arsenopyrite, without any apparent tendency to be controlled as to size or location by the enclosing sulphide.

(1) Gold was noted in arsenopyrite, distributed erratically throughout the constituent crystals of the more massive material. No gold was seen in the well crystallized type, but due to the small quantity of this present, the absence of visible gold could not be accepted as a definite indication of paucity of values in this case.

(2) No gold was observed in pyrrhotite or in the gangue minerals.

(3) One grain of gold occurred between cobaltite (?) and arsenopyrite (see Plate 4). Otherwise there is no apparent control of values by either cobaltite or lollingite.

Due to the extremely finely divided form of the gold, no quantitative analysis was attempted. At least 50%, however, is smaller than 2 microns in size, the remainder lying for the most part below 5 micrown, the largest observed being 7 microns in diameter.

In only a few cases was gold seen in arsenopyrite without etching by nitric acid. After etching with 1:1 HNO_3 for even a matter of seconds, however, numerous grains commonly appeared in a previously barren field. A notable feature was that every grain was

Plate 5

Gold in arsenopyrite (after etching). Note the "craters" surrounding each gold grain. The size of the photomicrograph represents a 200 mesh screen size. The largest grain visible is approximately 4 microns in diameter.

Plate 6

Gold grains in arsenopyrite (after etching). Note "craters" about grains. These grains are about 3 microns in diameter.

surrounded by a "crater" or "pit". (See plates 5 & 6)

A grain about 6 microns in size was observed in an unetched field of arsenopyrite (See Plate 7). At one end and extending partly down the side of the grain was a greyish substance, either a coating or a separate mineral, too small to allow of a determination of its true nature. After etching for 30 secs. with 1:1 HNO_3, the grain of gold was seen to be intact, but was surrounded by a "crater" of some size, the grey"mineral" having disappeared. The possibility of the gold being masked by a grey coating would therefore appear unlikely. Another grain, 5 microns in diameter, located in an unetched field was likewise partially enclosed by the same grey "mineral".

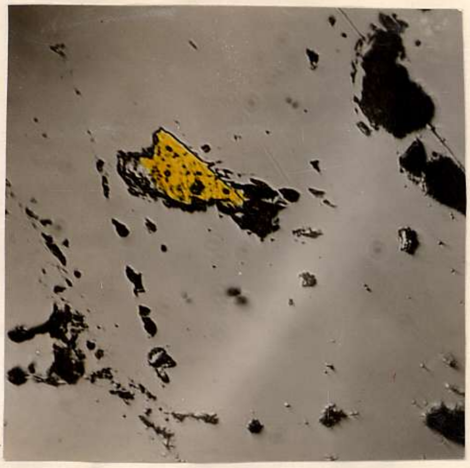
(1) The fact that gold appears readily, only after etching, is probably attributable to "smearing", the same difficulty being commonly encountered in attempting to study inclusions in argentiferous galena.

(2) The ubiquitous "craters", mentioned above, are probably due to electrochemical action between gold and arsenopyrite, or some coating on gold, and arsenopyrite. Data in this connection are lacking, but further research along these lines might be helpful in proving or disproving the presence of a coating on the gold.

(3) The grey "mineral" associated with the gold is easily soluble in nitric acid. As to its nature and composition it is at present impossible to hazard a guess.

<u>Gangue Minerals.</u> As only the reflecting microscope was employed the gangue minerals were not studied in detail.

<u>Calcite</u>.- coarsely crystalline masses and tiny inclusions in



Before Etching

After Etching

Plate 7

Grain of gold (5 microns in length) in arsenopyrite. Note grey mineral(?) at left end of gold grain before etching, and its complete removal after etching. Note also the extensive "crater" developed by etching.

sulphides. The calcite is relatively free from sulphides, and appears to be residual.

Silicates- include euhedral garnets, epidote, pyroxene, etc.

A plum-blue mineral is found in the gangue material and was at first mistaken for a metallic. It proved, however, to be transparent, highly pleochroic, with a high refractive index, and is probably axinite.

Paragenesis

(1) Inclusions of unreplaced silicates are common in the sulphides, even in massive arsenopyrite, where they commonly lie along crystal boundaries.

(2) Crystal boundaries of silicates have exerted definite directive influence on replacing sulphides.

Silicates appear to have preceded and to have been replaced by the sulphides, only garnet remaining immune.

(3) Arsenopyrite shows clearcut crystal boundaries against pyrrhotite, but holds inclusions of the latter, many along crystal boundaries as disclosed by polarised light, while no inclusions of arsenopyrite are found in pyrrhotite.

Arsenopyrite is probably older than pyrrhotite.

No criteria were noted for the definite determination of the age-relationships of lollingite or cobaltite. In plate 4, pyrrhotite occurs as islands in cobaltite(?) surrounded by arsenopyrite. Cobaltite might appear to be older than arsenopyrite. It is probably contemporaneous, however, as is lollingite.

Arsenopyrite replaced silicates in preference to calcite, although garnet was unaffected. Pyrrhotite likewise preferred silicates, replacing outwards from crystal boundaries for the most part. It appears to have had only a slight replacing power with reference to arsenopyrite.

All the gold observed under the microscopes appears to have been contemporaneous with arsenopyrite.

The following succession is suggested:

1. Formation of silicates.
2. Introduction of arsenopyrite, closely associated with cobaltite(?), lollingite, and gold.
3. Introduction of pyrrhotite, probably overlapping the end stages of arsenopyrite deposition.

Sample #2

"Pyrrhotite ore, 200 level, extremely high grade. Assay 7.80 ozs. per ton."

Megascopic

3 pieces of massive pyrrhotite were included in the section.

Microscopic

Pyrrhotite	Calcite
Arsenopyrite	Calcium silicates
Chalcopyrite	
Sphalerite	
Gold	

Pyrrhotite. Forms the bulk of the sample, coarsely crystalline as evidenced by polarised light, and containing as inclusions numerous small isolated masses of arsenopyrite and grains of gangue minerals, the distribution of both being apparently independent of texture within the pyrrhotite.

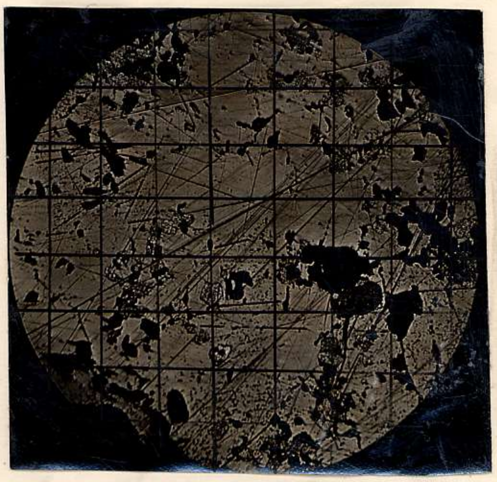



Plate 8

High grade Pyrrhotite showing disseminated arsenopyrite, and a few grains of gold. 100 mesh grid superimposed.

Arsenopyrite. Occurs as tiny subhedral or rounded grains throughout the pyrrhotite (see Plate 8), often as clusters or small masses, into which pyrrhotite has extended tongues along crystal boundaries. Blebs of pyrrhotite in arsenopyrite grains are common. A group of arsenopyrite "islands" commonly extinguish simultaneously over some area.

A micrometric analysis showed the following results:

FeAsS forms 12% of the section, distributed in the following size ranges:

150 microns		5.5%
-150	100 "	18.5%
-100	50 "	45.5%
- 50	"	31.5%

100 mesh		6%
-100	200 mesh	33%
-200	325 "	30%
-325	800 "	30%
-800	"	1%

Chalcopyrite. Present as small irregular masses in the pyrrhotite commonly against arsenopyrite, the largest observed being but 150 microns in diameter. Forms in the section examined, not over 0.5% of the whole mass.

Sphalerite. Noted in few instances as tiny isolated "islands" in the pyrrhotite.

Gold. Occurs as disseminated grains (from 91 microns down to submicroscopic size), scattered through the ore, commonly surrounded by or in contact with arsenopyrite, but in a few cases being found directly in pyrrhotite.

A micrometric analysis showed that visible gold, exceeding 3 microns in size, is sufficient to account for values between

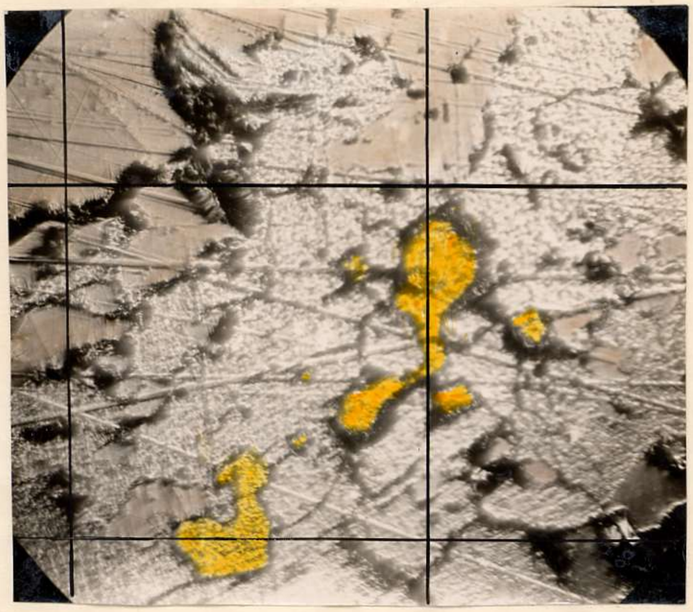


Plate 9

Typical occurrence of gold intimately associated with arsenopyrite in high grade pyrrhotite ore. 200 mesh grid superimposed.

Plate 10

Largest grain of gold observed (0.91 microns). Note close association with arsenopyrite.
200 mesh grid superimposed.

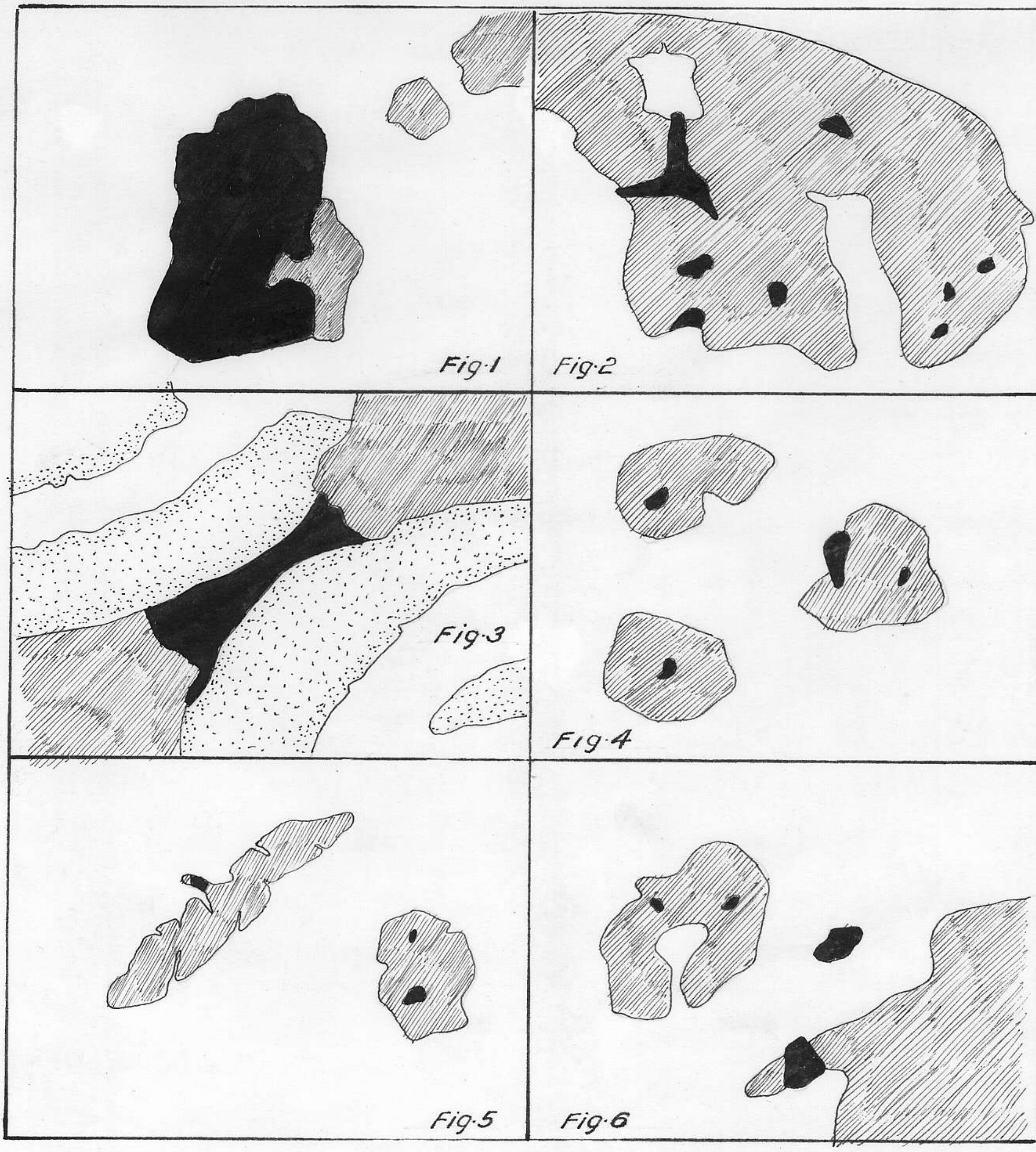


Plate 11

6 typical occurrences of gold in high grade pyrrhotite ore. Gold - black, Arsenopyrite - hatched, Chalcopyrite - stippled, and Pyrrhotite - white.
Camera Lucida drawings - Mag. x 500

8 - 10 ozs. per ton. Practically all the gold in this type of ore therefore exceeds 3 microns in size.

The size distribution is as follows of gold noted:

80 microns	--- 11%		200 mesh	--- 11%
-80 40 "	--- 14%	or	-200 325 mesh	-- 14%
-40 20 "	--- 63%		-325 800 "	-- 63%
-20 "	--- 12%		- 800 "	-- 12%

About 50% of the gold is directly associated with arsenopyrite, the remainder occurring partly in close proximity to arsenopyrite and partly as "islands" in pyrrhotite.

There is no necessity of etching this material to bring out the gold. For the sake of comparison with #1, gold in arsenopyrite was etched with 1:1 HNO_3 for up to 2 minutes without any tendency to exhibit the "craters" characteristic of the former sample. The gold is of a rich deep color, and no evidence of any associated grey "mineral" was seen.

Gangue Minerals. Calcite, epidote, garnet, and other silicates are present as inclusions in the sulphides.

Veinlets of calcite were also noted cutting through the ore.

Paragenesis

(1) Penetration of pyrrhotite tongues along crystal boundaries into masses of arsenopyrite with inclusions of pyrrhotite within arsenopyrite.

(2) Apparent lack of structural control of pyrrhotite upon the location of arsenopyrite grains.

(3) Simultaneous extinction of grains over some area.

Would seem to preclude the possibility of arsenopyrite being younger than pyrrhotite. On the other hand all three criteria, taken in conjunction, would strongly favor an older age for the arsenopyrite.

Gold would appear from Figs. 4 & 6 (Plate //) to be contemporaneous with arsenopyrite. This is in agreement with its general relations elsewhere in the section.

Chalcopyrite from Fig. 3 (Plate //) would seem younger than arsenopyrite and older than pyrrhotite. No other evidence was forthcoming.

The following paragenesis is suggested:

(1) Formation of silicates.

(2) Partial replacement of silicates by arsenopyrite accompanied by gold.

(3) Replacement of remaining silicates, and partial replacement of arsenopyrite by pyrrhotite and chalcopyrite.

(4) Veining of ore by later calcite.

Some gold may have been introduced with pyrrhotite, but the bulk of the gold is probably attributable to the arsenopyrite mineralization.

Sample #3

"Pyrrhotite ore with some chalcopyrite, 600 level, similar samples have been erratic and from former experience, we expected this sample to run about 0.30 ozs. Assay 0.72 ozs. per ton.

Megascopic

2 samples of solid sulphide ore were polished for examination. They were chosen to include both chalcopyrite and pyrrhotite in roughly equal proportions.

Microscopic.

Pyrrhotite	Calcite
Chalcopyrite	Silicates
Sphalerite	
Arsenopyrite	
Pyrite	

Pyrrhotite & Chalcopyrite. Form the bulk of the section. Each shows smooth contacts against the other, and apart from the vicinity of the boundary zone, each mineral is relatively free from inclusions of the other. Numerous tiny inclusions of gangue appear in both minerals, and both sulphides replace silicates out from crystal boundaries.

Sphalerite. Occurs as small rounded inclusions in both sulphides, and although forming a conspicuous constituent of the ore forms not over 2% of the section.

Arsenopyrite. Only 3 minute grains of this mineral, occurring as islands in pyrrhotite, were noted.

Pyrite. One small cube of pyrite was seen in pyrrhotite.

No gold was seen in this section.

Gangue. The usual gangue minerals are present in this section.

Paragenesis

Chalcopyrite, pyrrhotite, and sphalerite seem to be contemporaneous in this section, jointly replacing the silicates.

Sample #4

"Arsenopyrite ore, 500 level, has been running consistently low. Assay 0.30 ozs. per ton."

Megascopic

A section was prepared of two typical pieces of solid arsenopyrite ore.

Microscopic

Only arsenopyrite, pyrrhotite, and subordinate chalcopyrite, with typical gangue minerals were noted.

No gold was seen, but apart from the apparent absence of lollingite and cobaltite, and the slightly higher percentage of chalcopyrite, the section appeared identical to #1. Even the magnitude of crystallization in the arsenopyrite, as revealed by polarized light, was not materially different.

A definite age relationship between pyrrhotite and arsenopyrite was revealed in one place, however, and is reproduced in Plate 12 . Here pyrrhotite definitely fills fractures in arsenopyrite, and is consequently younger.

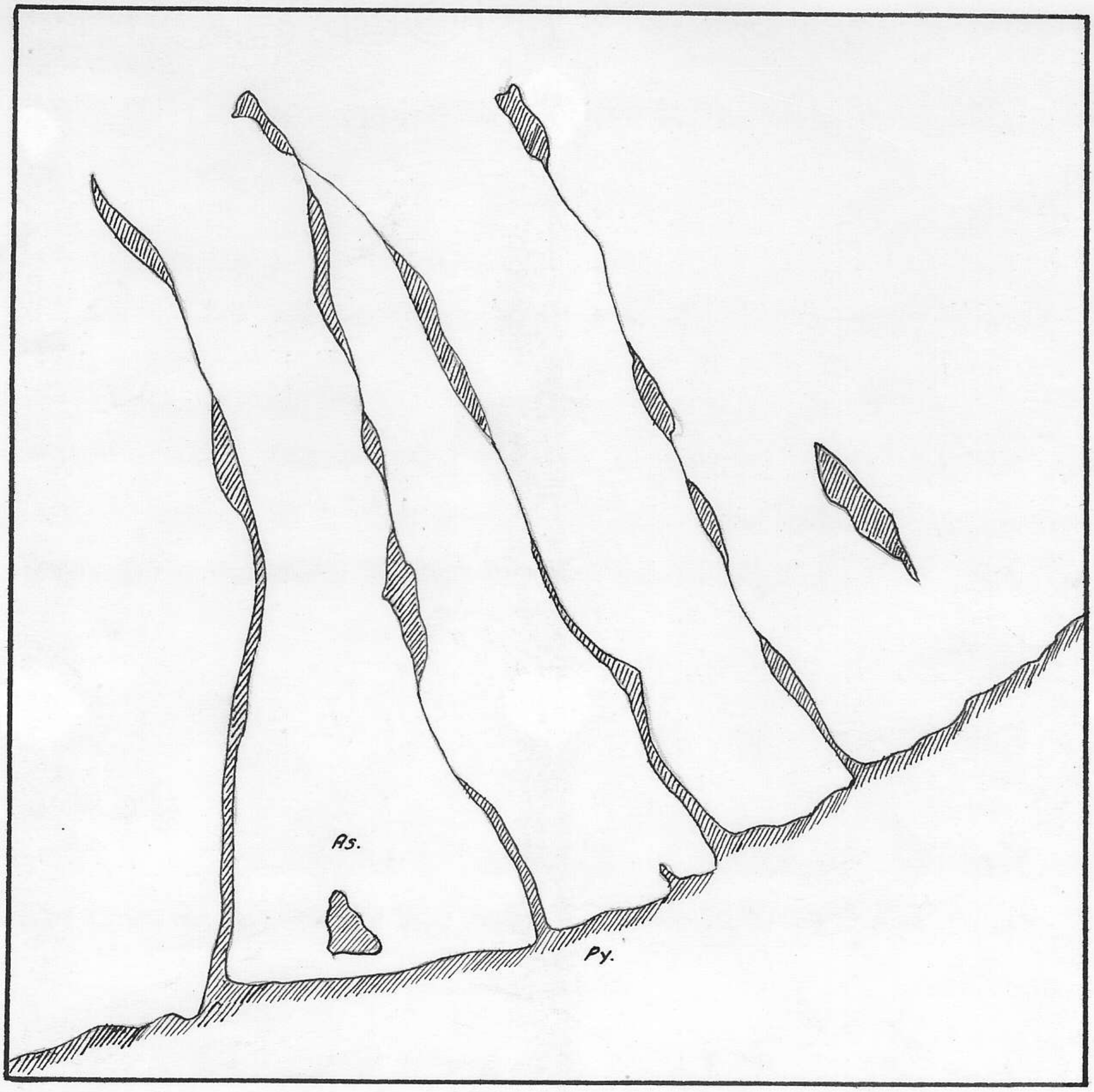


Plate 12

Pyrrhotite veining and replacing arsenopyrite along crystal boundaries and incipient fractures.

Camera Lucida drawing. Mag. x 1000

Sample #5

"Arsenopyrite ore, 600 level, usually low grade. Assay 0.58 ozs. per ton."

Megascopic

Two pieces of massive arsenopyrite were sectioned.

Microscopic

The general description of sample #4 will suffice here, except that 3 or 4 tiny grains of gold were noted in arsenopyrite. There is a slightly higher percentage of chalcopyrite here than in #4.

Sample #6

"Arsenopyrite, chalcopyrite, pyrrhotite ore, 1500 level, has been consistently low grade. Assay 0.16 ozs. per ton."

Megascopic

Two typical pieces were sectioned.

Microscopic

Arsenopyrite, chalcopyrite, pyrrhotite, and gangue are present in roughly equal amounts, accompanied by minor quantities of sphalerite.

No gold was seen.

Arsenopyrite is well crystallized, but contains inclusions of gangue minerals.

Pyrrhotite and chalcopyrite occur as irregular masses, apparently replacing gangue minerals and flowing around arsenopyrite crystals.

Where either chalcopyrite or pyrrhotite are in contact with arsenopyrite it is common to find tiny blebs and stringers of these sulphides in the latter.

The following paragenesis is suggested:

(1) Formation of silicates.

(2) Arsenopyrite replacing gangue minerals.

(3) Pyrrhotite, chalcopyrite, and sphalerite.

Summary and Conclusions

The following minerals were identified in the sections examined.

Arsenopyrite	Calcite
Lollingite	Garnet
Cobaltite (?)	Epidote
Unknown Grey Mineral	Other silicates
Pyrrhotite	
Chalcopyrite	
Sphalerite	
Pyrite	
Gold	

Comparison of high grade with low grade pyrrhotite ore

(1) High grade pyrrhotite ore contained arsenopyrite, in a finely divided form, making up about 12% of its volume; the low grade samples examined contained only negligible amounts of arsenopyrite.

(2) Chalcopyrite occurred in almost negligible amounts in the high grade ore while comprising a small but important constituent

of the low grade ore.

Comparison of high grade with low grade arsenopyrite ore

No distinct differences were noted between high grade and low grade arsenopyrite ore apart from the presence or absence of noticeable metallic gold. However:

(1) The high grade ore examined contained little or no chalcopyrite. A higher percentage of chalcopyrite was associated with the lower grades of arsenopyrite. There was likewise a slight increase in the amount of chalcopyrite with increasing depth.

(2) Lollingite, cobaltite, and the unknown grey mineral, were noticed only in the high grade ore.

As only one section of each type of ore was prepared and examined, however, it is not suggested that the above be accepted as generalizations.

Gold

Comparison of gold in high grade arsenopyrite with that in high grade pyrrhotite

(1) Gold is present in a finely divided form (from 7 microns to limit of microscopic resolution), scattered erratically through arsenopyrite without any apparent control by contacts, crystal boundaries, fractures, etc. Gold occurs more coarsely disseminated through high grade pyrrhotite (91 microns to 3 microns) and is usually, though not always, closely associated with arsenopyrite grains.

(2) In only two cases was gold noted before the arsenopyrite ore had been etched with nitric acid, the application of this reagent, even for a few seconds commonly sufficing to bring out a number of grains, in an otherwise apparently barren field; there was no

necessity to etch pyrrhotite ore to bring out the gold.

(3) Each gold grain in arsenopyrite ore, after etching, was surrounded by a "crater". No such craters appeared after etching pyrrhotite ore, even where the gold grains were completely enclosed by arsenopyrite.

(4) Two grains of gold were noted in arsenopyrite without etching. In each case a grey mineral(?), completely removed by subsequent etching, was noted in intimate association with the gold. No such grey mineral(?) was noted with the gold in pyrrhotite ore.

Discussion

(2) As pointed out in the body of this report, the failure of gold grains to appear in high grade arsenopyrite, without etching, is probably attributable to "smearing", although why the effect should not extend to gold in high grade pyrrhotite as well is hard to explain.

(3) The ubiquitous "craters" found about gold grains after etching high grade arsenopyrite, are probably due to some electro-chemical action along the contacts. The question is, however, if the action is attributable to the potential differences between gold and arsenopyrite alone, why "craters" are not formed about gold particles enclosed by arsenopyrite in the high grade pyrrhotite ore. Whether the difference in effect is attributable to a coating of some sort on the gold in one case or the other is at present unknown, but ?further research along these lines might be merited to find whether a coating exists, and if so, its amenability to flotation or cyanidation.

(4) The grey mineral(?) associated with gold in the arseno-pyrite ore, might be, in reality, nothing more than lead gouged from

the polishing lap during the process of preparation. The fact, however, that it was noted only in two places, and then only in intimate association with gold, would make this appear exceedingly unlikely, when it is considered that in all the sections polished, under identical conditions, no other indication of such a possibility was forthcoming. Here again would seem a suggestion for further research - to determine the nature of the coating, if possible, and the extent of its occurrence.

Paragenesis

The following paragenesis is suggested.

1. Formation of silicates.
2. Introduction of arsenopyrite.
3. Introduction of pyrrhotite, chalcopyrite, and sphalerite.
4. Fracturing and veining of ore by calcite stringers.

2 & 3 probably overlapped to some extent. The relations between pyrrhotite, chalcopyrite, and sphalerite are not clear but these minerals are probably contemporaneous in the main.

Arsenopyrite has replaced silicates preferentially over calcite.

Pyrrhotite and chalcopyrite likewise replaced silicates preferentially - their replacement of arsenopyrite has not been extensive.

The major part of the gold appears contemporaneous with arsenopyrite. Some gold may be associated with the other sulphides but did not appear under the microscope.