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THE MINERALIZATION OF THE FRENCH MINE, HEDLEY, B.C.

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Thirty-five polished sections, one thin section, and numerous hand specimens from the French Mine were examined for this report.

Regional Geology Reference

The French Mine is located within Nickle Plate Mountain, in a skarn zone in Lower Triassic argillites, limestones and volcanics (Nicola Group). These rocks are intruded by thin gabbro and diorite dykes and sills. Rocks in the area are broadly folded, and fold axes plunge gently northwest. Local crumpling of beds formed passageways for ore-bearing fluids. Many ore-zones follow these local folds, which are called "Morning Crumples". These ore-bodies are characterized by their roughly circular cross-sections about 25 feet in diameter and their lengths of several hundred feet.

Mineralization is confined to the skarn zone, which forms a halo around ore-bodies. It is possible that skarn was developed by the intrusions, which were prior to folding. Skarn became highly fractured during folding, while unmetamorphosed sediments underwent plastic deformation. Fractures in skarn, which were most numerous in local crumples, formed passageways for ore-bearing fluids.

Megascopic Examination

Two types of mineralization were observed in hand specimens. Most mineralization occurs in skarn which is generally greenish coloured, fine-grained, hard and tough. Some crystals of diopside up to ½ inch long were observed. Specific gravity of one specimen of skarn is 3.50. Some mineralization occurs in veins (?) of coarsly crystalline calcite.

Molybdenite occurs as irregular blebs and along fracture planes in skarn. It displays characteristic platy habit and bluish colour in this ore.

Sulfides of copper (principally bornite and chalcopyrite) occur as isolated irregular blebs, and occasionally as massive material, in skarn. In massive material chalcopyrite and bornite are in equal abundance, and chalcopyrite appears to form rough veins in bornite.

Tellurides in hand specimen occur as irregular blebs in skarn, and appear to be of two types. Most grains are tin white with a faint bronze-yellow tarnish and a high metallic lustre. This material has hardness 2 and excellent prismatic cleavage. It encloses native gold in one specimen. One large grain has a distinct black tarnish, platy habit, and hardness 2.

Arsenopyrite occurs as coarse prismatic deeply striated crystals in coarsly crystalline calcite. Arsenopyrite was identified by its crystal form, greyish-white colour, and hardness of 5. A microchemical test for cobalt was negative.

Thin Section Examination

The thin section is 50% diopside, 45% neutral coloured garnet, and 5% opaque minerals. Diopside and garnet are fine-grained, angular and subhedral to anhedral. These minerals appear to have formed simultaneously, and the opaque minerals, which formed later, occur as irregular blebs and stringers of grains. Most opaque minerals are in garnet in this thin section.

Microscopic Examination

1. Arsenopyrite FeAsS

This mineral occurs in rounded and diamond-shaped grains. Colour is white (faint tan in contact with cobaltite), and characteristic anisotropism is observed in most sections. Hardness is F. This mineral is stained iridescent by HNO_3, all other etch tests are negative. Grain size up to ½ inch.

2. Safflorite $(Co,Fe)As_2$

Safflorite of the Hedley type has the same optical properties as arsenopyrite. It can be identified by its anisotropism, cubic crystal outline, and positive microchemical test for cobalt. HNO_3 slowly stains black, $HgCl_3$ and $FeCl_3$ slowly stain light brown; all other etch tests are negative. It is often observed in contact with arsenopyrite and cobaltite.

3. Cobaltite CoAsS

Colour faint pinkish white, polish good, hardness G, isotropic. HNO_3 stains faintly iridescent, all other etch tests negative. Grains up to 2000 microns are generally rounded, but cubic crystal outline is sometimes evident.

4. Nicolite NiAs

Nicolite, which is uncommon in ores from B.C., forms about 20% of one section. It has replaced arsenopyrite and has been partly replaced by chalcopyrite. It is identified by its bright pinkish colour, hardness E, moderate pleochroism and strong anisotropism. HNO_3 tarnishes with efforvescence, $HgCl_2$ stains brown to iridescent. It occurs as angular blebs, from 10 to 200 microns wide, in arsenopyrite.

5. Bornite Cu_5FeS_4

Bornite is identified by its pinkish-brown colour, hardness B, weak anisotropism and positive microchemical test for copper. Bornite occurs as massive material with chalcopyrite and arsenopyrite in one section, and as isolated grains in several sections.

6. Chalcopyrite $CuFeS_2$

Chalcopyrite is distinguished from gold by its superior hardness and positive etch test with HNO_3 (fumes tarnish faintly). Chalcopyrite is brittle compared to gold. Chalcopyrite shows well-developed exsolution textures with bornite in this ore: it has exsolved along (111) and along grain boundaries of bornite (see Figure 1). It also forms irregular veins in bornite. Very fine grains of tellurides have grown in chalcopyrite in one section.

7. Chalcocite Cu_2S

This mineral was tentatively identified by its hardness B, characteristic bluish-grey colour, and association with other copper sulfides. It was observed under high power as veinlets in bornite up to 5 microns wide and 50 microns long. In a few places it has formed as small embayments along bornite grain boundaries, and in one instance it has replaced part of a chalcopyrite veinlet.

8. Tetrahedrite $(Cu,Zn,Fe)_{12}Sb_4S_{13}$

Tetrahedrite is observed under high power in the section of massive sulfides. It is tentatively identified by its isotropism, grey colour, and association with copper sulfides. Occasionally it has higher relief than bornite, hence it probably has hardness greater than B. Tetrahedrite almost invariably forms at grain boundaries between chalcopyrite and bornite (see Figure 2), although usually a band of chalcopyrite up to 4 microns thick separates it from bornite. It has a mutual boundary texture with chalcopyrite, and its formation appears to be controlled by chalcopyrite-bornite contacts. It occasionally occurs as embayments along bornite grain boundaries.

9. Joseite A $Bi_{4+x}Te_{1-x}S$

Joseite B $Bi_{4+x}Te_{2-x}S$

Both joseite A and joseite B have been identified in this ore by other workers, using x-ray methods. They are optically indistinguishable. In polished sections joseite is light greyish white, slightly to moderately anisotropic, with hardness about B. Etch tests are: HNO_3 etches dark grey with slight efforvescence, $FeCl_3$ stains blue-grey after one minute, HCl stains light grey after one minute, all other etch tests negative. This mineral forms grains up to ½ inch in this ore, but most grains are from 50 to 200 microns across. It occurs commonly with gold, and also intercalated with molybdenite and bismuth.

10. Hedleyite $Bi_5Bi_2Te_3$

Hedleyite is optically almost indistinguishable from joseite. In this ore it is slightly whiter, and occasionally has a stipled surface. Etch tests can be used to distinguish them: HNO_3 efforvesces quite vigorously and etches dark grey, $FeCl_3$ slowly stains brown (stain difficult to rub off), all other etch tests (including HCl) are negative. Hedleyite occurs as small blebs up to about 100 microns, and is associated with gold, and bismuth.

11. Bismuth Bi

Bismuth is white with a distinctive pinkish cast, hardness B, and variably anisotropic. HNO_3 etches grey with efforvescence, HCl stains dark brown, $FeCl_3$ stains iridescent, all other etch tests negative. Bismuth occurs in this ore as isolated blebs up to 150 microns wide, as very thin veinlets in skarn, and as lamellae intercalated with molybdenite.

12. Molybdenite MoS_2

Molybdenite is a common constituent of this ore. It is easily recognised by its characteristic white to purplish pleochroism, and intense distinctive anisotropism. Hardness is B. Etch tests are all negative. Molybdenite commonly occurs as bent plates, size ranges from "needles" a few microns wide to laths up to 500 microns wide. It occurs with bismuth and the tellurides, and in one instance it has been partly replaced by gold in a spectacular myrmekitic intergrowth (see figure 3).

13. Gold Au

Gold is distinguished by its characteristic colour, hardness and sectility. It is weakly anisotropic in some of this ore, but usually it is isotropic. Some gold occurs as rounded blebs, about 10 microns wide, enclosed in arsenopyrite, but most gold seen occurs with tellurides and molybdenite. Generally gold occurs as irregular to rounded blebs, some up to 1/8 inch, but it also occurs as myrmekitic replacements of molybdenite and tellurides. Commonly blebs of gold associated with tellurides lie at the edges of telluride grains.

Mode of Mineralization

Opaque minerals form about 10% of the specimens examined, and all minerals are primary. Chalcocite and tetrahedrite may be exsolution products of bornite and chalcopyrite. Some chalcopyrite appears to have exsolved out of bornite.

Chalcopyrite	17%
Arsenopyrite	15%
Bornite	15%
Cobaltite	15%
Safflorite	10%
Molybdenite	10%
Nicolite	5%
Joseite A & B	4%
Hedleyite	2%
Bismuth	2%
Gold	2%
Tetrahedrite	2%
Chalcocite	1%

Type of Deposit

This is a pyrometasomatic deposit of arsenides, sulfides, tellurides and gold in skarn. Skarn probably was formed prior to introduction of opaque minerals.

An interesting thermal history is indicated by the paragenetic sequence and exsolution textures. The arsenides (with some gold) were deposited first, probably at temperatures greater than 500°C. Copper sulfides were deposited at about 500°C. Tetrahedrite appears to have exsolved out of chalcopyrite and segregated along chalcopyrite grain boundaries, indicating that this ore was held at a high temperature, below 500°C, for a period long enough to allow segregation. Exsolution textures of chalcopyrite in bornite are preserved however, indicating that this ore was cooled slowly to 475°C, and rapidly cooled after this. Hence mineralization occuring after emplacement of copper sulfides probably occurred at temperatures between 475° and 500°C.

A possible paragenetic sequence is

1. Arsenopyrite with minor Gold
2. Safflorite
3. Cobaltite

4. Nicolite
5. Bornite
6. Chalcopyrite (some as exsolution out of Bornite)
7. Chalcocite (exsolution product)
8. Tetrahedrite (exsolution product)
9. Joseite
10. Hedleyite
11. Bismuth
12. Molybdenite
13. Gold

Molybdenite usually forms at high temperatures, but textures indicate that it was one of the last minerals to form in this ore.

Problems Expected in Ore Dressing

Most visible gold occurs as particles larger than 10 microns, but a significant portion occurs as smaller particles in arsenopyrite, so very fine crushing of this ore is necessary to free gold from host minerals. Iron sulfides are not present in this ore, so excessive consumption of oxygen in cyanide is not expected. However, economic quantities of copper sulfides are present. Bornite in particular is likely to react with cyanide solutions, so if possible it is suggested that copper sulfides be floated off before cyaniding this ore. No particles of gold were observed in the copper sulfides. No oxidized antimony or copper minerals are present to cause excessive consumption of cyanide.

TEXTURES

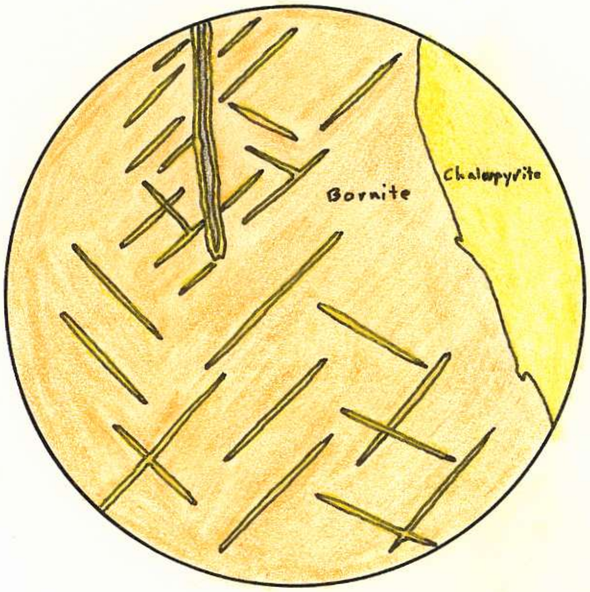


Fig. 1 Field 500 microns

Exsolution of chalcopyrite out of bornite. Tetrahedrite has also exsolved out of bornite.

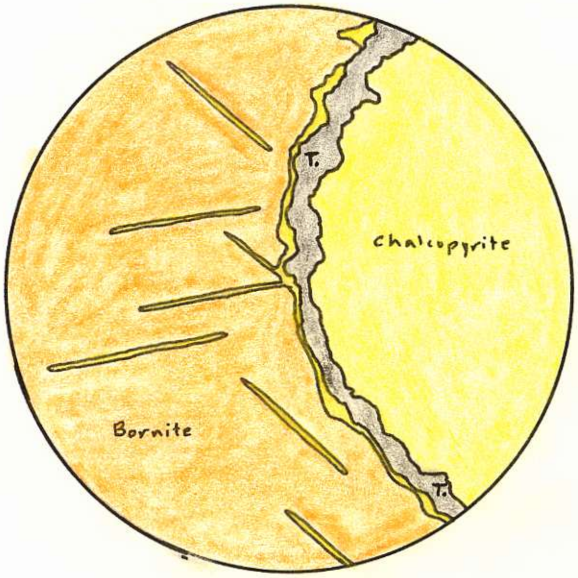
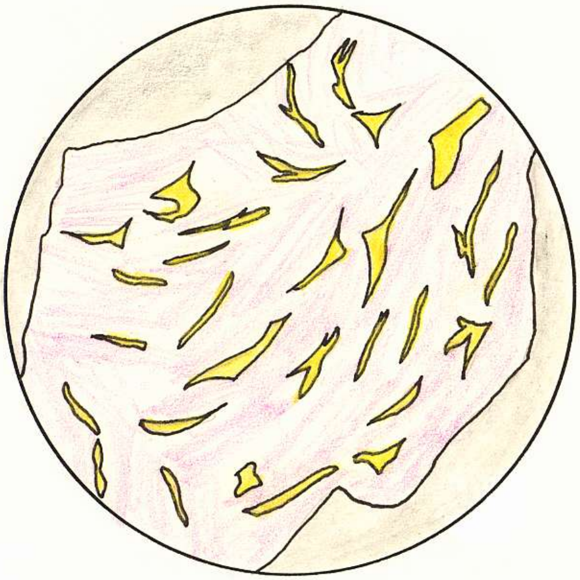


Fig. 2 Field 500 microns

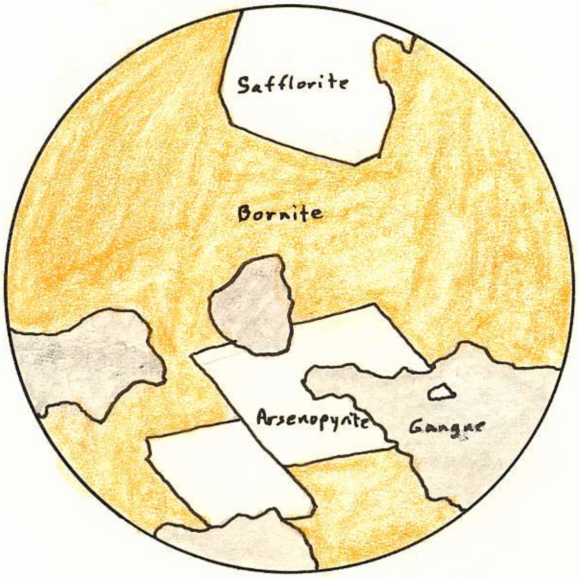
Possible sequence to explain this texture:

1. Emplacement of copper sulfides at T > 500°c
2. Cool slowly to 475°c. Tetrahedrite (T.) segregates along grain boundaries of chalcopyrite
3. Fast cooling from 475°c partly preserves exsolution texture of chalcopyrite in bornite, although some chalcopyrite segregates to edge of bornite.



Molybdenite partly replaced by gold.

Fig. 3 Field 1500 microns



Euhedral crystals of arsenopyrite and safflorite in bornite

Fig. 4 Field 3000 microns

Gold has partly replaced hedleyite, and laths of molybdenite appear intercalated with joseite

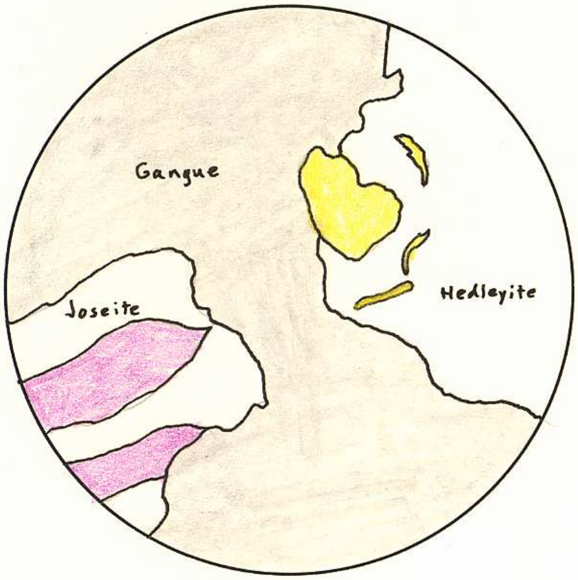


Fig. 5 Field 1500 microns

Molybdenite has partly replaced arsenopyrite which contains small blebs of gold.

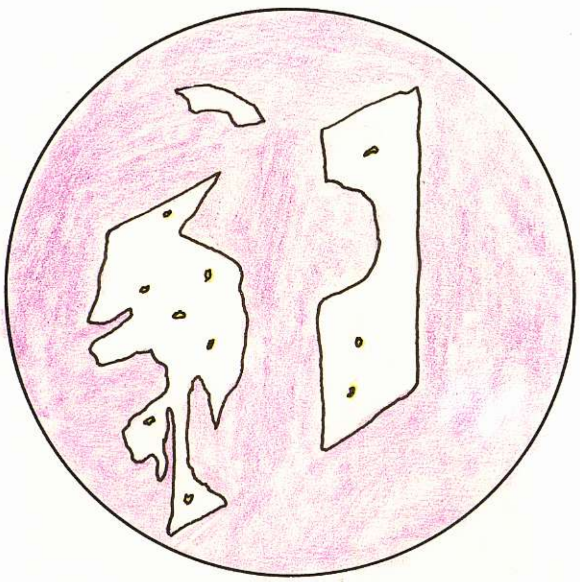


Fig. 6 Field 1500 microns

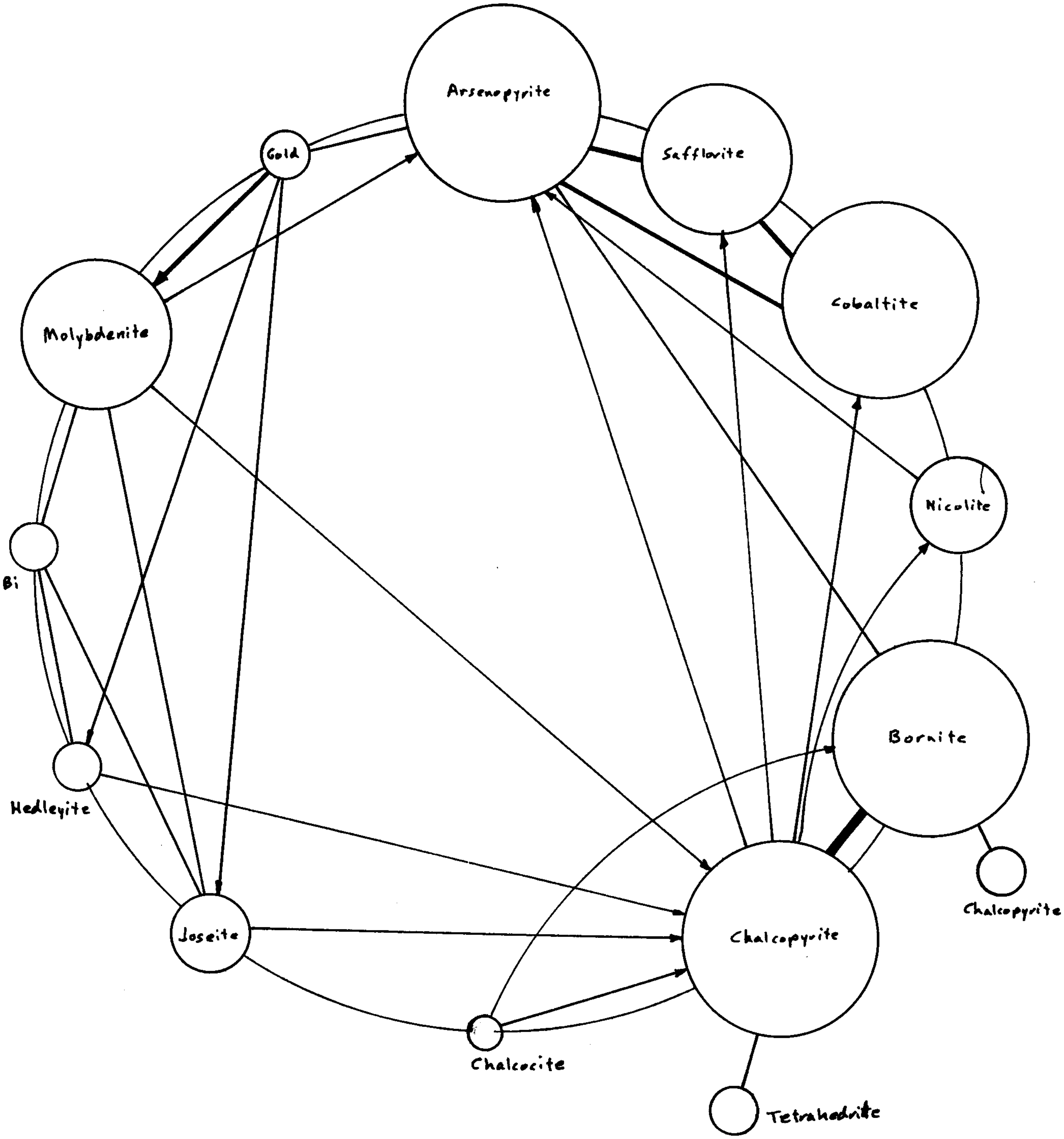


Fig. 7 Van Der Veen Diagram