A STUDY OF ORE MINERALS
FROM THE PREMIER MINE

R. Harrison
1966

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Introduction

The Silbak Premier Mine is located in north-western British Columbia, about 150 miles north of the city of Prince Rupert. The property is only 11 miles from the head of the Portland Canal, a natural fjord that penetrates in from the coast for almost 50 miles.

Although noted as a major silver-lead producer, the Silbak Premier has also yielded substantial amounts of gold, zinc, and copper. The suite of specimens examined in this study are from a "high-grade" lens that was found to outcrop on the wall of the abandoned glory hole.

History of the Mine

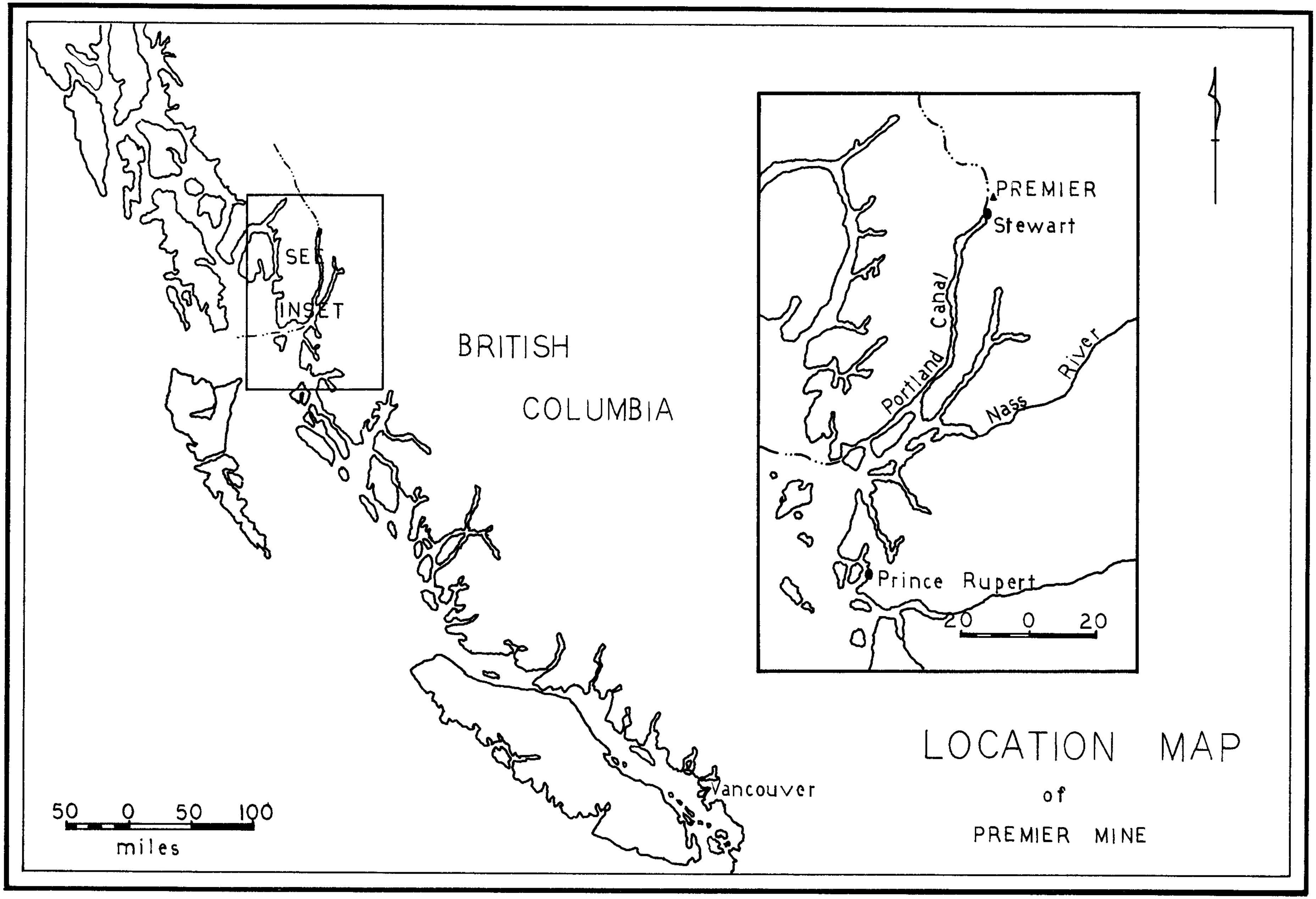
In 1910 and 1911, the high-grade gold and silver veins were discovered, and in 1916 underground development commenced. The low prices of the base-metal market forced operations to cease in 1953, but the mine reopened two years later. Fire destroyed the mill and surface workings in 1956 and another low priced market closed the mine the following year. In 1959 the upper part of a high-grade ore lens found on the south side of the abandoned glory hole was mined, and subsequent underground exploration has since begun.

Early values were recovered as a cyanide precipitate and also as table and flotation concentrates. After 1933 all the ore had been milled and values recovered in concentrate form. By the end of 1947, the original mine had yielded 1,736,248 oz. of gold and 36,703,762 oz. of silver.

Development of the high-grade lens has produced about 2736 tons of ore (as of 1961):

gold	18,595 oz.
silver	394,933 oz.
copper	16,258 lb.
lead	215,989 lb.
zinc	322,118 lb.

Total reserves at this time were estimated to be around 169,346 tons.



LOCATION MAP
of
PREMIER MINE

Regional Geology

The mine is located just beyond the eastern contact of the Coast Batholith intrusions. The dominant rocks are a series of volcanic tuffs, andesites, and agglomerates, interbedded with and overlain by slates and conglomerates.

Alteration of the country rocks is often intense, with an extremely varied assemblage of chlorite, calcite, epidote, sericite, and silica.

Mineralized veins occur along strong fracture zones that exist where the tuffaceous Jurassic rocks have been intruded by a granodiorite-porphyry dyke system. The relatively small size and scattered occurrence of the ore lenses has complicated further search for mineralization.

Ore Studies

Megascopic Descriptions

A large assortment of hand-specimens were examined for initial identification of both the ore and gangue minerals. The larger specimens gave some indication of the wall-rock alteration and the possible type of deposit; the smaller specimens consisted mainly of massive ore.

High-grade Samples:

Some of the high-grade ore samples have a very porous yellow-orange gossan on the surface. This porous texture suggests near-surface weathering and subsequent removal of some of the material. Limonite is common, associated with silicates that have undergone alteration to kaolinite, sericite, and minor chlorite. Well-developed minute crystals of clear quartz have grown in some of the cavities, suggesting that the ore deposit may have been developed, at least in part, as a vein replacement along partially-open fractures.

Massive galena, disseminated pyrite and chalcopyrite, and some sphalerite constitute most of the visible sulfide mineralization. Electrum, pyrargyrite (?), and native silver are also present in minor amounts.

Most of the pyrite is present as euhedral to subhedral crystals. The galena also shows evidence of well-developed cystals.

Massive-ore Samples:

Much of the massive ore is quite fine-grained galena, sphalerite, chalcopyrite, and some tetrahedrite, with larger grains of pyrite and pyrrhotite (?). In some of the samples there is a suggestion of a "banded" appearance, possibly the result of vein deposition. The silver-(and gold)-bearing minerals are generally not conspicuous except for occasional tiny veins of "slugs" of electrum that appear to have been deposited later than most of the common sulfides.

One sample that suggests a visible contact between the ore minerals and the enclosing rock indicates that the wall-rock alteration may have been quite pervasive--for an undetermined distance--with both pyrite and, rarely, thin veinlets of galena associated with the zone of alteration.

The larger well-developed crystals of galena often have a somewhat irridescent tarnish, probably the result of a film of secondary covellite.

Pyrite is frequently associated with veins of dirty-white quartz, ¼" to ½" wide, that appear to have preceeded the deposition of most of the ore minerals. In places, these quartz veins are vuggy and often have good crystals (of quartz) developed in the cavities.

Quartz-vein Samples:

Large specimens of massive quartz have fractures ¼" wide of less that are filled with electrum and native silver. Tetrahedrite, galena, and chalcopyrite are also present, the latter two commonly with a covellite film on the exposed surface.

Most of the quartz appears to have been fractured prior to mineralization (?) and the ore minerals have been introduced along these planes of weakness. Some of the silver minerals seem to show a vague dendritic pattern.

Gangue Mineralogy:

The composition of the original country rock is uncertain as the rocks have been quite highly altered in the immediate vicinity of the mineralized zone. Quartz and feldspar are common, and the development of sericite and kaolin attests to the alteration of these two minerals. Calcite is present in some samples.

Apatite is believed to be present, developed as a yellow-white dull mass on a few specimens. However, this was not confirmed definitely by the (poor) phosphate test.

? Occasional small patches of a pinkish-red mineral may be rhodonite or rhodochroisite, formed by the action of hydrothermal fluids on Mn-bearing minerals present in the intruded rock.

Limonite, kaolin, and some calcite are a common assemblage in some of the coloured gossan.

Secondary Cu minerals not given.

Microscopic Descriptions

The following is a list of the minerals identified with the aid of microscope. The minerals are listed along with their identifying physical properties and chemical and etch tests where applicable.

Pyrite: (FeS_2)
Rough polish, generally pitted surface; pale yellow colour; H = 6; some euhedral grains, generally corroded and replaced by later minerals, especially galena and sphalerite; assoc. with galena, sphalerite, chalcopyrite, and electrum commonly, also with tetrahedrite; grain sizes extremely variable, from 1500microns to less than 20.5 microns.

Galena: (PbS)
Good polish, triangular pits common on surface; white-grey colour,; $H = 2\frac{1}{2}-3$; black streak; good cubic crystal outline common; Isotropic; cleavage occasionally obvious; some grains show evidence of stress and fracturing; assoc. with all minerals, most common with sphalerite and chalcopyrite; grains sizes ranged from 3500 microns down to approx. 27.0 microns.

Chalcopyrite: ($CuFeS_2$)
Good polish; bronze-yellow colour; $H = 3\frac{1}{2}$; black streak; massive texture; commonly as exsolution in sphalerite; assoc. with galena, sphalerite, tetrahedrite commonly; also with all other minerals to lesser degree; grain sizes: 950 microns down to 15.5 microns.

Sphalerite: (Zn(Fe)S)
Moderate polish; brownish-grey colour; $H = 3\frac{1}{2}$; generally massive texture; very weakly anisotropic on some grains; internal reflection yellow-white; assoc. with all minerals except native silver and argentite (?); occasionally show caries texture against galena; grain sizes vary from 360 microns to less than 50 microns. Carries exsolution chalcopyrite of less than 4 microns.

Tetrahedrite: ($(\mathrm{Cu, Fe, Zn, Ag,})_{12}\mathrm{Sb}_4\mathrm{S}_{13}$)

Good polish; colour darker gray against galena; generally grey-brown; H = 3½-4; dark streak; irregular grains common texture; no anisotropism; associated intimately with polybasite; also with electrum and chalcopyrite and native silver; grain sizes from 300 microns to 90 microns.

Etch: HCl...tarnish vague; irridescent
$\mathrm{HNO_3}$..sligh brown stain
Aqua Regia...stained very dark

Polybasite: ($\mathrm{Ag_{12}Sb_2S_{11}}$)

Good polish; appears as a blue-grey colour against tetrahedrite; H = 2-3; very faintly pleochroic (?); texture revealed by anisotropism: blue-grey to green-grey; assoc. with native silver, chalcopyrite, tetrahedrite, sphalerite and galena; grain sizes from more than 2500microns to 120 microns, the smaller sizes are more common.

Etch: KCN...blue-brownish ring around drop, no stain
HCl...slight tarnish (?)
$\mathrm{FeCl_3}$.. somewhat irridescent stain
Microchem: Ag test positive; Cu present also.

Electrum: (Au-Ag)

Generally bright polish; colour bright yellow; commonly with scratches; H = 2½ - 3; streak is a bright whitish-yellow; massive; assoc. commonly with tetrahedrite, chalcopyrite, galena, and polybasite; often appears to be in fractures in the earlier minerals; grain sizes are 3000microns to less than 60 microns.

Etch: KCN...stains differentially...shows up differences in composition (?)

Covellite: (CuS)

Poor polish; grey to blue in colour; blue colour not usually conspicous at first; often as a reaction rim around tetrahedrite and galena and sphalerite; slight pleochroism; anisotropism strong; (also occurs as a film on chalcopyrite in the hand-specimens); grain sizes very small: 4 - 10 microns approx.

Native Silver: (Ag)

Good polish; white to cream in colour; $H = 2\frac{1}{2}-3$; bright streak; often difficult to distinguish from electrum; generally occurs as veins cutting earlier minerals; under crossed-nicols, there isn't complete extinction; assoc. with chalcopyrite, polybasite, tetrahedrite, and galena; grain sizes are 22 microns to about 7.0 microns.

Etch: KCN...negative.

Argentite: (?) (Ag_2S)

Fair polish; grey-green against galena; $H = 2-2\frac{1}{2}$; definitely softer than galena; isotropic (?); appears in contact with galena along gangue-filled vein; grain size 15 to 5 microns.

Etch: $FeCl_3$...slight stain (?)
KCN....brownish tarnish
All other standard reagents negative.
Possibly light-sensitive.

Summary of grain sizes (in microns):

mineral	size range	average size
argentite	15 - 5	10 - 5
chalcopyrite	950 - 15.5	100 and less
covellite	10 - 4	same
electrum	3000 - 60	500 or less
galena	3500 - 27	1000 or less
native silver	22 - 7	15 - 10
polybasite	2500 - 120	400 or less
pyrite	1500 - 20.5	300 - 50
sphalerite	360 - 50	200 - 50
tetrahedrite	300 - 90	same

Textures and Relationships

Textures Observed:

Primary:

1. Banded...a suggestion of crustified banding of the ore minerals in veins and fissures.
2. Caries...typical of the boundaries between many of the sulphides, especially galena, sphalerite, and chalcopyrite.
3. Granular (Mosaic)...seen in some sections and in the hand-specimens. Pyrite, galena, and to a lesser degree, sphalerite.
4. Crystallographic...very striking feature of the chalcopyrite-sphalerite exsolution.
5. Mutual Boundaries...applies to most of the minerals, especially those exhibiting so-called caries texture.
6. Porphyritic...euhedral crystals of pyrite (and galena) in gangue matrix ?
7. Wire texture...occasionally shown by electrum and native silver.

Secondary:

1. Brecciated...shown by some of the crystals of pyrite and by much of the galena.
2. "Ice cake"...pyrite enclosed in later galena and sphalerite.
3. Reaction Rim...rim of covellite on tetrahedrite, galena, and occasionally sphalerite.
4. Veined...later mineral such as electrum and native silver (and tetrahedrite) vein early sulfide minerals.
5. Replacement...common; illustrated in the paragenesis.

Relationships:

Pyrite appears to be the earliest mineral formed and although many of the grains have been fractured or partially replaced by the later sulfides, etc. many of the euhedral to subhedral outlines are still obvious.

Ideally, on the basis of structure, sphalerite is generally thought to be formed before galena. However, in this deposit galena appears to be the earlier mineral, as suggested by (a) euhedral crystal outlines of galena against sphalerite, and (b) replacement of galena by sphalerite to a limited extent. However, both of these minerals, along with the chalcopyrite exsolved from the sphalerite, appear to represent almost synchronous deposition.

Some of the galena developed as euhedral to anhedral crystals, many of which show deformation and fracturing probably due to later movement within the deposit.

Very minute (less than one micron) bright "spots" in the galena are thought to possibly be silver, but this could not be confirmed.

Most of the sphalerite is rich in exsolved chalcopyrite. Other large concentrations of chalcopyrite are thought to have been deposited slightly later.

Tetrahedrite shows slight evidence of replacing the earlier minerals, and is commonly found associated intimately with polybasite. The latter may have been introduced along the grain boundaries of the tetrahedrite.

Secondary covellite may have developed from both chalcopyrite and tetrahedrite, but it is most often associated (in polished sections) as a reaction-rim product between tetrahedrite and galena. A similar relationship also appears possible between the tetrahedrite (and/or galena) and the chalcopyrite-sphalerite exsolution mixture. The covellite is sometimes removed from contact with tetrahedrite...a result of migration along grain boundaries?...and deposited preferentially on the galena.

Electrum and native silver vein the earlier minerals. Etching reveals slight compositional differences within the electrum, and the gradation from the gold-silver mixture to native silver appears impossible to discern.

The presence of argentite was not positively confirmed, but was suspected as a late vein mineral in contact with galena and possibly tetrahedrite.

Illustrations:

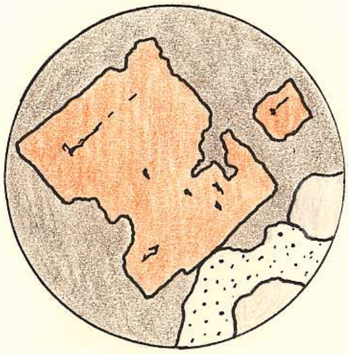


Figure 1.

Euhedral crystals of early pyrite (orange) enclosed and corroded by sphalerite (brown). Minor galena (rgey-white) has mutual-boundaries relationship against the sphalerite. (X40)

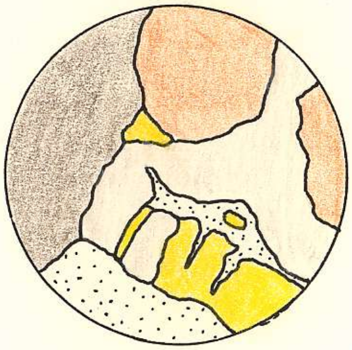


Figure 2.

Intimate mixture of sulfides that typifies much of the ore. The pyrite (orange) has been rounded and corroded, but the sphalerite (brown), galena (grey-white), and chalcopyrite show evidence of being deposited at approximately the same time. (X400)

Figure 3.

Euhedral to subhedral grains of galena enclosed in a matrix of gangue minerals. The galena has been partially replaced by sphalerite (brown) that contains some exsolution chalcopyrite. (X400)

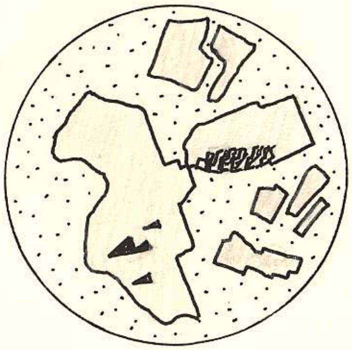


Figure 4.

Grains of galena that show evidence of post-deposition movement and subsequent fracturing. (X100)

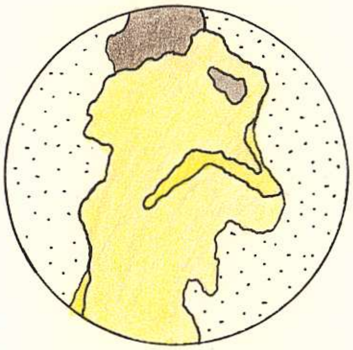


Figure 5.

Electrum, in contact with sphalerite and enclosing an irregular grain of tetrahedrite (grey). Etching of the electrum reveals what may be a composition difference...brighter yellow indicating a zone with a greater percentage of gold?
(X100)

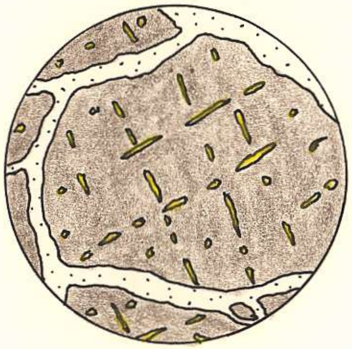


Figure 6.

Sphalerite (brown) with the exsolved chalcopyrite aligned along crystallographic planes. This is a very striking feature of much, but not all, of the chalcopyrite-sphalerite unmixing.
(X100)

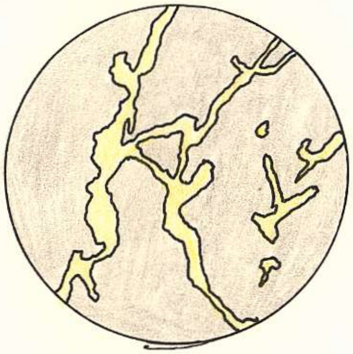


Figure 7.

Irregular veins of native silver cutting massive tetrahedrite. Some of these veins may be electrum rather than native silver.
(X400)

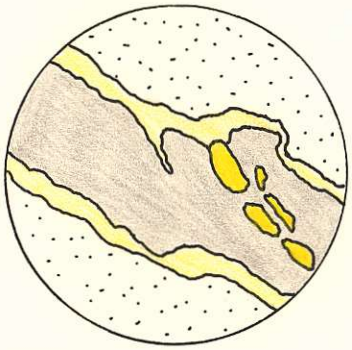


Figure 8.

A mineralized vein in gangue (stippled). The suggested sequence of deposition...chalcopyrite, followed by tetrahedrite and both preceeded by native silver (?)...seems to be the opposite of that suggested in the paragenetic sequence.
(X400)

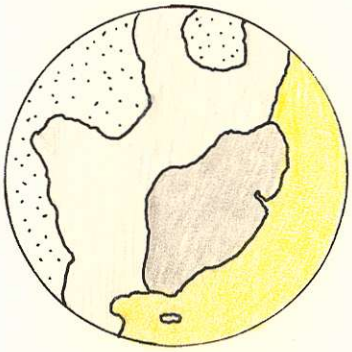


Figure 9.

Galena (grey-white) in contact with, and possibly replaced by, tetrahedrite (grey) and electrum (yellow). The electrum may have replaced the tetrahedrite to some extent.
(X400)

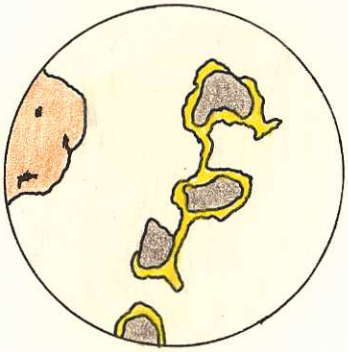


Figure 10.

Sphalerite (brown), with an exsolution rim of chalcopyrite (yellow), enclosed in galena. The relationship suggests that the sphalerite may have been earlier than the galena. A corroded grain of pyrite (orange) is also enclosed by the galena.
(X400)

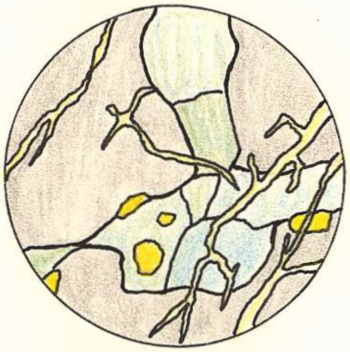


Figure 11.

Complex relationships between tetrahedrite (grey), polybasite (grey-blue to grey-green under crossed nicols), chalcopyrite (yellow), and veins of electrum (± some native silver).
(X100)

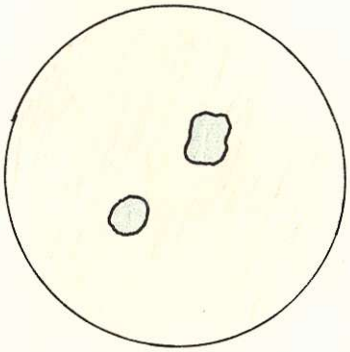


Figure 12.

Rounded grains of polybasite enclosed in galena. The smooth and regular boundary contacts is typical between polybasite and galena and also tetrahedrite.
(X400)

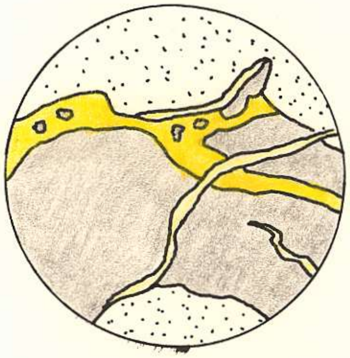


Figure 13.
Tetrahedrite (grey) veined by chalcopyrite (yellow), and both of these minerals in turn veined by electrum.
(X100)

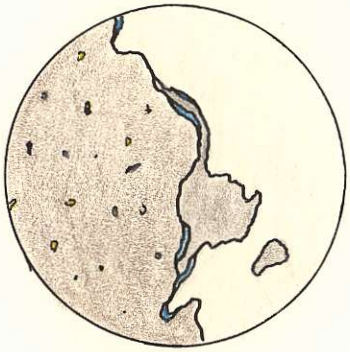


Figure 14.
Minor tetrahedrite (grey) between galena (grey-white) and sphalerite (brown). The sphalerite has minor amounts of exsolved chalcopyrite and an undetermined grey-coloured mineral. Reactions between the tetrahedrite and/or the sphalerite has produced covellite (blue), some of which may have migrated along the grain boundaries.
(X400)

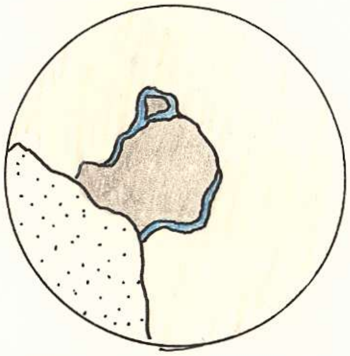


Figure 15.
Covellite (blue) developed between tetrahedrite (grey) and galena (grey-white).
(X400)

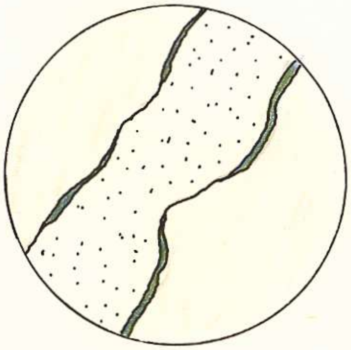


Figure 16.
Suspected argentite (green-grey) against galena along a contact between the galena and gangue (stippled).
(X400)

Relative Percentages

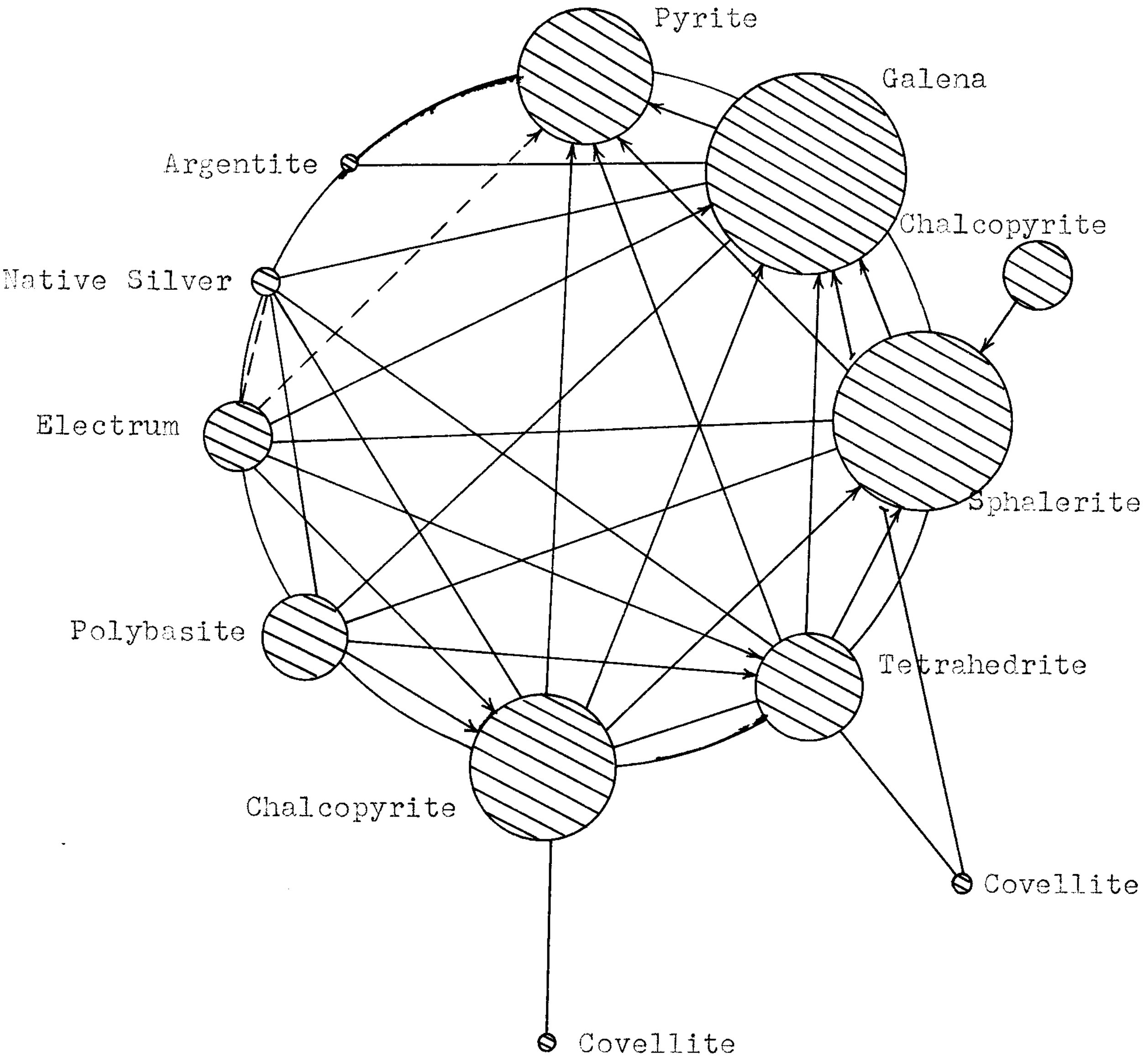
These are the percentages of the ore minerals, relative to one another, and based on an average of all the polished sections that were studied. Proportions will vary in different zones, and individual minerals may be absent in some of the ore.

Galena	26.0 %
Sphalerite	22.0 %
Chalcopyrite	17.0 %
Pyrite	12.0 %
Tetrahedrite	9.0 %
Polybasite	6.0 %
Electrum	4.5 %
Native Silver	1.5 %
Covellite	1.0 %
Argentite (?)	1.0 %

Minerals such as limonite (and pyrrhotite?) that were observed only in the hand specimens have not been included in these percentages.

The amount of electrum, native silver and covellite appears to be much higher in the hand specimens than in the polished sections. It is therefore felt that estimates of ore grade based solely on hand specimens are likely to be misleading.

Paragenetic Sequence



Van de Veer Diagram

Type of Deposit

The presence of low-temperature minerals such as native silver, electrum, and argentite (?), accompanied by the sulfides chalcopyrite, galena, and sphalerite, represents an assemblage often classified as an epithermal deposit. These deposits are considered to have developed at temperatures between 50 and 200 degrees centigrade.

However, solutions of chalcopyrite in sphalerite unmix at about 350 to 400 degrees centigrade, and the sulfosalt tetrahedrite is generally considered to be found more commonly in this higher temperature range. Therefore, there is an indication that the temperature of formation was somewhat greater than that given as the upper limit of epithermal-type deposits.

The association with volcanic rocks, the localizing of the ore along fracture zones, and the possibility of the granodiorite-porphyry being an off-shoot from the main batholith complex all typify features that are considered relatively common of epithermal deposits.

Within the mineralized zone, the gangue associates, suggestion of vein replacement and banding, and wall-rock alteration support the possibility of mineralization occurring at relatively shallow depths (less than 5000') and at fairly low temperatures. Such deposits often show "telescoping"...rapid near-surface deposition that has led to a zoning of the mineralization and often a deposit of lateral rather than vertical extent.

Ore Dressing Considerations

Gangue Mineralogy:

The abundance of silica (quartz) in the gangue may necessitate long and slow grinding. Such an operation could result in the ore being "over-ground" to such an extent that later recovery of the ore minerals will be made increasingly difficult.

Carbonate minerals in the gangue (calcite, rhodochrosite ?) may hinder the concentration of ore by flotation techniques.

The presence of somewhat reactive minerals...calcite, sericite, minor feldspar...might be an aid in arresting the process of oxidation of the ore minerals. However, quartz (and rhodonite?) are to be considered detrimental in this respect and may introduce complications in the flotation processes.

Not So
hot

Ore Mineralogy:

The somewhat complex mixture of electrum, native silver, and sulfides may require careful consideration of the sizes to which the ore will be ground. "Briquetting" ...a microscopic statistical analysis of grain size, percentages, and associations...might prove valuable in determining grinding sizes.

Much of the exsolution chalcopyrite would undoubtedly be too fine for mechanical seperation, and generally 40 to 60 microns is considered the limit of commercial recovery for many copper-lead-zinc ores.

Effective liberation of much of the ore might be obtained by cyanidation, but the presence of pyrite, pyrrhotite (?), and copper sulphides would tend to consume the cyanide rapidly.

Tailings should be examined periodicly, especially when production has just commenced, to see if the gold and/or silver is being missed due to oxidation coatings on the mineral or because the grinding is too coarse.

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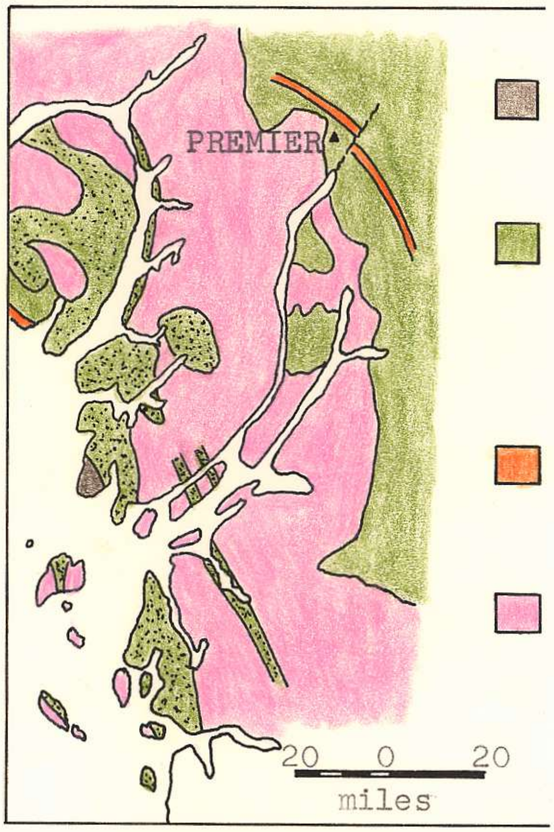
Appendix



REGIONAL GEOLOGY

🟫 U. Jurassic - L. Cretaceous: clastics with granitic debris

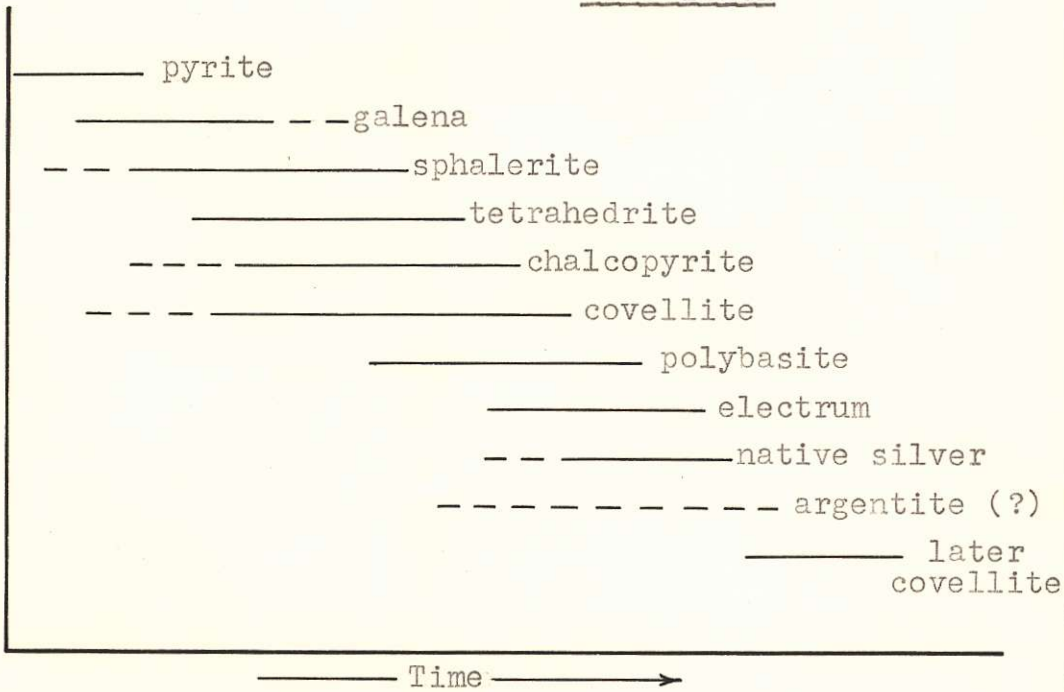
🟩 U. Triassic - U. Jurassic: andesitic lavas, pyroclastics, with muddy and limey sediments.
(Metamorphosed... ░)

🟧 Young intruded granitic rocks.

🟪 Granitoid rocks of metamorphic origin.

(after W. H. White, 1966)

DEPOSITION



Diagrammatic presentation of the possible times of deposition of the ore minerals of Premier Mine.