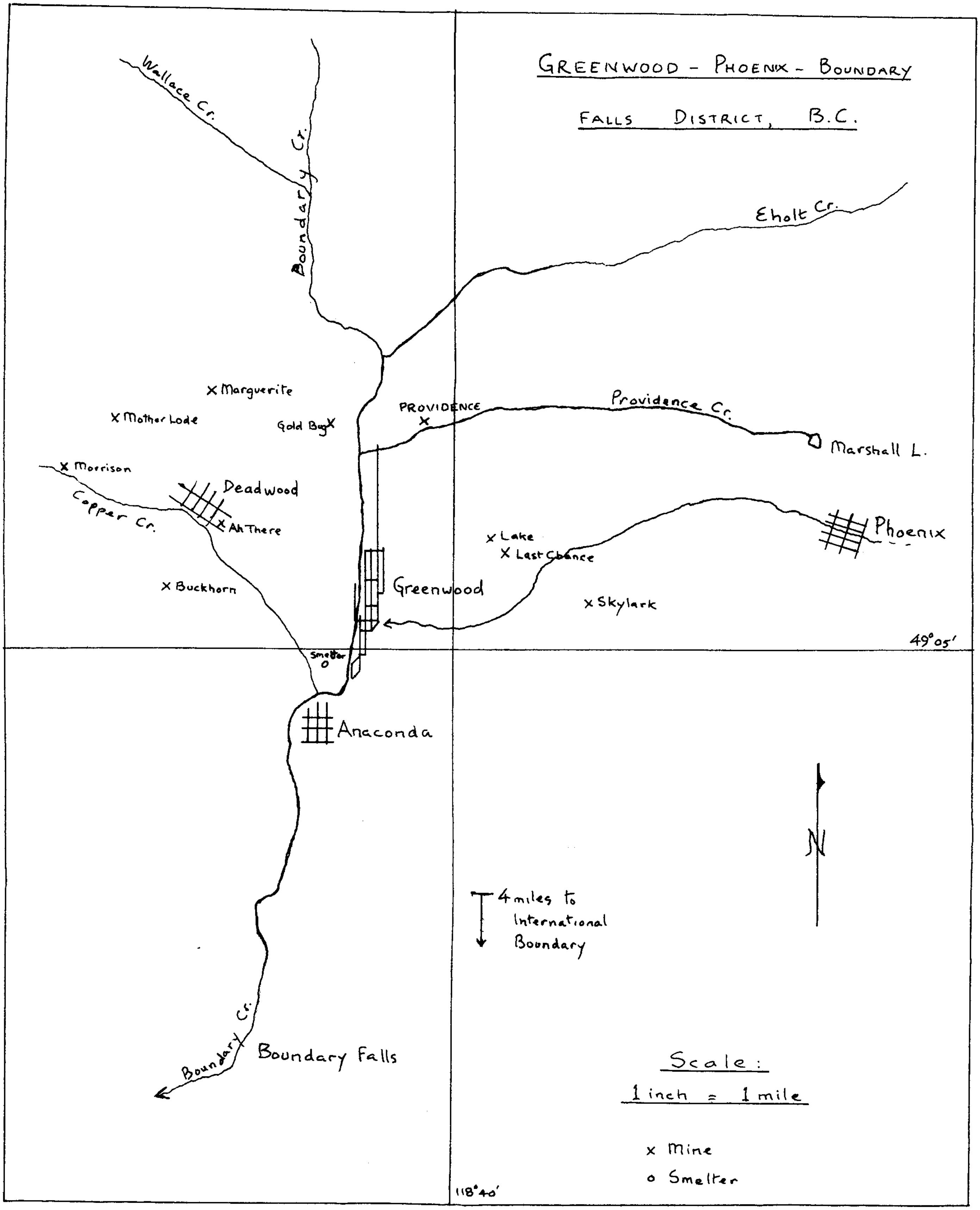
P.J. Street

GEOLOGY 409

Problem #4

ORE SPECIMENS FROM THE PROVIDENCE MINE, GREENWOOD, B.C.



[The railroad and main highway follow the valleys of Boundary and Eholt Creeks.]

ORE SPECIMENS FROM THE PROVIDENCE MINE,

GREENWOOD, B.C.

Introduction:

The present report describes specimens from the Providence mine, which is one of several mines in the Greenwood district of British Columbia.

Greenwood is located about 26 miles by road west of Grand Forks on the Trans-provincial Highway #3, and is about six miles north of the international boundary, as shown by the enclosed sketch-map. The Kettle Valley line of the Canadian Pacific Railway also passes through Greenwood, and extensive branch-lines and sidings attest the former level of mining activity in the district. The once-prosperous Deadwood and Phoenix mining camps are in the same general district, and the Midway district is a few miles to the west or south-west.

The district was first prospected in 1892, very shortly after the first major activity in the Rossland area. The major attraction was the self-fluxing low-grade copper ores of the Phoenix camp, which were present in high volumes although disappointing in grade. By 1916 Phoenix had the largest copper operation in the British Commonwealth, and there were smelters at Greenwood and Boundary Falls as well as Grand Forks. However, the deposits were worked out by 1918.

Gold and silver mining has been carried on sporadically in the Greenwood district since that time, and the Providence mine itself has been worked at intervals for over 50 years. It is currently owned by W. Madden and leased by W. McArthur of Greenwood. In the late '30s considerable repair, reconditioning and exploratory work was done, and production jumped from 81 tons in 1939 to 1280 tons in 1940 and 1899 tons in 1941. However, it declined steadily to 172 tons in 1946, and does not appear to have shipped any ore since that time, though some exploratory and development work has been done almost every year between 1950 and 1956. [New para.] The mine is approximately 1½ miles north of the town of

Greenwood near the confluence of Providence Creek and Boundary Creek, and is readily accessible by road.

Geology:

The Providence deposits consist of a single major mineralized quartz vein, with associated minor veinlets and some replacement bodies immediately adjacent to it. The fortunes of the mine have apparently fluctuated with the persistance or lack of persistance of this vein.

The mine country-rock is mostly sheared and silicified argillites and volcanics at the northern contact of the Greenwood granodiorite batholith. (Perhaps it should be referred to as a stock, as it is not more than two or three miles wide at Greenwood. However, Warren and Watson (1937) refer to it as the Greenwood batholith). The vein strikes N 50° E and dips 40-65° SE, cutting across the argillites, volcanics and some granodiorite bodies. It has been traced underground for over 1200 feet, and ranges from less than an inch to over 2½ feet wide. In some places it widens slightly at its intersections with pre-mineral faults, but it pinches in passing from silicified rock to chloritic schist. It is reported to be more persistant in silicified rock than in the granodiorites. These are small irregular bodies rather than the Greenwood batholith itself, though they are considered t o be closely related to it. Warren and Watson report that the vein cuts "augite porphyrites", agglomerates and porphyritic tuffs, all of which are highly metamorphosed and of indeterminate structure. (The B.C. Department of Mines Bulletin #20 says that the argillites have a north-easterly dip).

The vein is cut by minor faults, and post-mineralization syenite-porphyry dykes are common.

Elsewhere in the district there are andesite and latite flows and limestones, intruded by pyroxenite, "gabbro diorite" and granodiorite (B,C. Dept. of Mines). The limestones have been locally metamorphosed to skarns; (in the Phoenix camp, most of the copper ores are in skarns).

The Knob Hill volcanics and cherty quartzites, the Rawhide argillites and the Brooklyn chert-breccias, conglomerate and limestone are all of unspecified Paleozoic age, and the Greenwood batholith and stocks are said to date from the Jurassic or Cretaceous. The Midway volcanics (not actually found near the Providence mine) and the syenite-porphyry dykes are probably not older than Late Tertiary.

<u>The Specimens</u>: Megascopic Examination.

The suite consists of several polished sections, about a dozen chip samples, one piece of split core, and about two dozen larger handspecimens.

The polished sections had deteriorated slightly as a result of previous work, and fresh sections were made of eight representative specimens.

The core, chip samples and handspecimens show little variation in character, but fall into two main groups. Accordingly they will be described as such rather than individually.

i) The smaller group consists mainly of massive, coarsely-crystallized sphalerite and galena, in approximately equal amounts, with up to 10% tetrahedrite. In places the galena forms wedge-like masses that penetrate the sphalerite. Both the sphalerite and the galena show good cleavage faces. There are traces of chalcopyrite in the sphalerite. Blebs of quartz may be scattered through the massive sulphides.

ii) The main bulk of the specimens consists of quartz vein material. The quartz is a dull milky-white rather than clear, and in the larger specimens is thoroughly fractured by what may be tension-fractures.

These fine fractures are generally discoloured by the presence of sulphide minerals; these are in very small amounts, and die out altogether at the extremities of the fractures that are farthest from the main concentrations of sulphides.

Elsewhere the quartz appears to be in rounded or angular fragments with a matrix of sulphide minerals. It occasionally shows good prismatic crystal form, which suggests at least two different stages of quartz crystallization. The massive anhedral quartz has apparently been sheared and brecciated; sulphide mineralization has then 'cemented' or replaced the quartz, and the later euhedral quartz has been deposited either with the sulphides or soon afterwards. The unpolished part of specimen #8 provides a good example of this.

There is abundant evidence of shearing at two or more stages. One stage, as suggested above, may have provided access for mineralization; and post-mineralization shearing has produced many slickensided surfaces, which in many cases have abundant chlorite. Pyrargyrite is to be seen in fragile flakes smeared over these sheared surfaces.

Calcite is intimately associated with the quartz, both as grains of microscopic size and as coarse euhedral crystalline masses which may be up to 1½"or 2" long. It frequently contains fairly well-crystallized grains of pyrite, chalcopyrite, and sometimes pyrrhotite.

The sulphide minerals in this group consist mostly of galena and sphalerite as in group (i), but in proportions that vary greatly from one specimen to another. The amount of tetrahedrite varies likewise. Other minerals present are chalcopyrite, pyrrhotite and probably native silver, all in considerably smaller amounts than the first three, but readily visible.

Smeared on some of the fracture surfaces, or protruding from fractures, is a dark-grey or blackish, soft, pliable metallic mineral of flaky habit, at first identified as argentite. However, it lacked the perfect sectility of argentite, and a sample was X-rayed by the powder method. The pattern obtained closely resembles that of stephanite, a rare silver sulpho-salt with the composition $5Ag_2S.Sb_2S_3$. The X-ray data are given on page 5.

X-ray Powder Photograph. STEPHANITE $5Ag_2S.Sb_2S_3$.

X-3198
Fe/MnO
March 9 '61

ASTM 2-0620

Intens.	R	L	Sum	R-L = 2θ	'd' meas.	comp'd with
1	58.6	27.0	85.6	31.6	3.56	
1	59.5	26.1	85.6	33.4	3.37	
10	61.1	24.5	85.6	36.6	3.085	ASTM 3.03; Harcourt 3.06
5B	62.2	23.3	85.5	38.9	2.909	
1	63.3	22.5	85.8	40.8	2.78	
8	64.9	20.8	85.7	44.1	2.580	
1	65.6	20.2	85.8	45.4	2.51	
1	66.1	19.5	85.6	46.6	2.45	
1	67.4	18.4	85.8	49.0	2.34	
½ line						
2B	70.0	15.8	85.8	54.2	2.13	
several lines						
2B	74.5	11.3	85.8	63.2	1.849	

Specimens 'C' and 'N' have appreciable amounts of stephanite in flaky masses.

Microscopic Examination:

Minerals:

1) Sphalerite: grey, hardness C, isotropic, resinous-brown internal reflection under arc light, polishes well but is left with a slightly pitted surface.
2) Galena: galena-white, hardness B, perfect cubic cleavage, with both rectangular and triangular cleavage patterns; cleavage lines frequently distorted into a curve in these specimens.
3) Pyrite: pale brass-yellow, hardness F, poor polish with pitted

surface, isotropic.

4) Chalcopyrite: brassy-yellow, more yellow than pyrite, with hardness C, weakly anisotropic, black streak, no cleavage.

5) Pyrrhotite: very pale yellow or cream with slight pinkish cast, hardness D, fair to good polish but rougher surface than chalcopyrite, strongly anisotropic with colours from bluish-grey to reddish-brown.

6) Tetrahedrite: grey, hardness D, isotropic, KCN stains yellowish-brown, all others negative except aqua regia which stains it eventually, and HCl which darkens it slightly (hardly a stain).

7) Native silver: white but rapidly acquiring a pinkish cast as it tarnished in air after polishing; hardness B, isotropic when fresh, good polish.

8) Stephanite: hardness B, strongly anisotropic dark grey to very light grey, powders when scratched, negative to most reagents but tarnishes brown with $HgCl_2$; no internal reflection.

9) Argentite (?): dull grey, but with bluish rather than greenish cast, hardness B or B-, isotropic, apparently sectile; not positively identified, but present in Polished Section #7, about 2 mm in from the edge at point marked by arrow in bakelite mount.

10) Unknown: dark grey, darker than tetrahedrite, hardness probably D, present in lath-like crystals interlocking with tetrahedrite; present in Section #7 very close to Mineral #9.

Minerals 9 and 10 were overlooked at first. After they were observed, insufficient time remained to make further tests for identification.

11) Pyrargyrite: white or slightly bluish-white, hardness C, very slightly anisotropic, but identified immediately by its brilliant red internal reflection, which is frequently visible even through an overlay of gangue minerals.

Textures:

Section 1:

Pyrite, of which there is a particularly high proportion in this section, is automorphic, imposing its crystal form on the sphalerite which is the next most abundant mineral here. Galena is interstitial to the first two, but appears to have penetrated the sphalerite and has perhaps replaced it. There are blebs of tetrahedrite in galena and vice versa, but no conclusive evidence as to prior deposition. A few small veinlets or blebs of native silver occur in the sphalerite, but the sphalerite is virtually free of silver minerals in most of these sections.

Section 2:

This section, and section 6, show the most interesting textures of the suite. It is illustrated in Plate 1.

Irregularly-shaped blebs of tetrahedrite are randomly scattered throughout the galena, and these are marked by their *
greater hardness and isotropism. Blebs of similar colour, but anisotropic and of a hardness closer to that of galena, are believed to be stephanite and are generally elongate or arranged in lines, their orientation generally oonforming with the cleavage directions of the galena. Occasionally there are two sets of blebs intersecting almost at right angles, and it is usually found that the blebs within each set are in parallel optical orientation, but that one set will be extinguished when the other set is bright, and vice versa.

Section 6 shows particularly good examples of "swarms" of blebs, analogous on a microscopic scale to dyke swarms in appearance though not of course genetically.

This is interpreted as very strong evidence in favour of the exsolution of stephanite from galena. Tetrahedrite also occurs as isolated blebs and is likely to have exsolved from the galena, but it appears to truncate sets of stephanite blebs in places, and is probably later than the stephanite.

Etching with HNO_3 produced a very delicate dendritic texture in the galena. The dendrites appear~~ed~~ to ~~be~~ have grow~~ing~~n out from the cleavage lines, and strongly resembled the most highly developed forms of ammonite sutures. Bastin mentions dendrites as characteristic of replacement textures, and this may be a case of guided penetration along cleavage lines. The 'replacing' mineral was too fine to identify with certainty, but its white colour with a slight pinkish cast suggested native silver.

Section 3:

This section shows some larger grains of the mineral believed to be stephanite, sometimes with mutual boundaries between tetrahedrite and galena, and in places totally enclosed by tetrahedrite. There is very little pyrite in this section, and it occurs as small isolated automorphic grains. There is very little sphalerite, and tetrahedrite accounts for the bulk of the sulphide minerals. The quartz gangue is present as scattered grains of irregular outline; the unpolished counterpart of this section appears to consist of brecciated quartz in a sulphide-mineral matrix.

The textural relationships suggest deposition of pyrite, sphalerite and galena in that order; tetrahedrite has subsequently replaced the bulk of the galena and perhaps some sphalerite. Plate 2 illustrates a portion of the section consisting mostly of tetrahedrite, in which a large isolated grain of galena remains. The lath-like shadows in the galena are cleavage cracks. Chalcopyrite is present as fine veinlets in the tetrahedrite, and may be a replacement of the latter. The evidence of Plate 3 is inconclusive, but the scattered particles of galena in tetrahedrite may be residual, the tetrahedrite having replaced the bulk of it.

Section 4:

Most of the metallic minerals in this section are associated with calcite and quartz rather than with quartz alone.

Ruby silver (pyrargyrite) occurs in fractures in the gangue and, very rarely, interstitially with the chalcopyrite and galena. In Plate 4 it may be located by the arrows on the margin of the photograph.

There is very little sphalerite in this section, and the textures suggest the replacement of galena and pyrite by chalcopyrite.

Section 5:

The textures illustrated in Plate 5 show simple mutual boundaries, and offer little useful evidence about the order of deposition. The crystallographic continuity of the galena, which forms the main mass, may suggest that it is older than the sphalerite and chalcopyrite. However, Plate 6 shows the penetration of sphalerite by galena, and this has occurred to a greater extent than the photograph is able to show. It was impossible to outline the intergrowth of tetrahedrite and galena, which is very intricate. But the tetrahedrite is concentrated near the contact with the sphalerite, close to the centre of the photograph, and the texture suggests replacement of galena by tetrahedrite and also by chalcopyrite (there are small blebs of this in the galena.)

The section has conspicuous grains of native silver, visible to the naked eye. There are also isolated grains of pyrargyrite in fractures in the quartz gangue. The quartz is thoroughly fractured, and would probably require little crushing to release the metallic minerals.

The native silver contains blebs of tetrahedrite which are of irregular outline but are definitely elongate, and aligned in a parallel orientation with one another. The texture suggests that the tetrahedrite has begun to replace the silver by guided penetration, but it is unusual to find silver in any but the last position in a paragenetic sequence. There are also silver grains with both a rim and a core of tetrahedrite. The two textures described in this paragraph were unfortunately both observed after the photographs were taken.

Section 6:

This consists mainly of sphalerite and galena, the latter having penetrated and probably replaced the former to some extent, but in any case being later in order of deposition. The textures produced by the exsolution of stephanite from galena have been described in connection with Section 2. Plate 7 illustrates a portion of the section where tetrahedrite is comparatively abundant, and it is difficult to say whether it has exsolved from the galena or has replaced it. The blebs suggest exsolution but the larger masses and the boundary relationships suggest replacement.

Section 7:

Plate 8 shows textures strongly suggesting that the order of deposition was, consecutively, pyrite, sphalerite and galena, with exsolution of tetrahedrite from galena. In general, the textures resemble those of Sections 1 and 3.

Section 8:

Pyrrhotite is more in evidence in this section than in the others, but in general has been encountered far more rarely in this suite than was expected. Earlier writers have described the Providence vein as a "pyrrhotite-ruby silver deposit", but the specimens examined on the present occasion contain only very small amounts of these two minerals. The pyrrhotite occurs in fractures in the quartz gangue, together with galena and chalcopyrite. It has irregular boundaries with these minerals and shows no particularly diagnostic textures.(Plate 9)

Plates 10 and 11 were taken with medium and high power objective lenses respectively, and illustrate specks of calcite gangue that contain minute needle- or wire-like particles of a mineral believed to be pyrrhotite. The only positive etch test produced an iridescent tarnish on the small metallic inclusions when KOH was applied. Unfortunately the calcite gangue was completely destroyed by HCl, but the arrow cut in the bakelite mount points to the cavity formerly occupied by the calcite.

Conclusions:

The presence of stephanite, not only in quartz fractures as flakes, but also as exsolution bodies throughout the galena, suggests that the property may be more valuable as a silver producer than for its gold, of which no trace was seen by this writer. Stephanite with a composition of $5Ag_2S.\ Sb_2S_3$ is considerably richer in silver than pyrargyrite $3Ag_2S.Sb_2S_3$.

The deposit is probably of the mésothermal hypogene type, since the minerals cover a wide range of temperatures, yet there is no evidence of supergene mineralization.

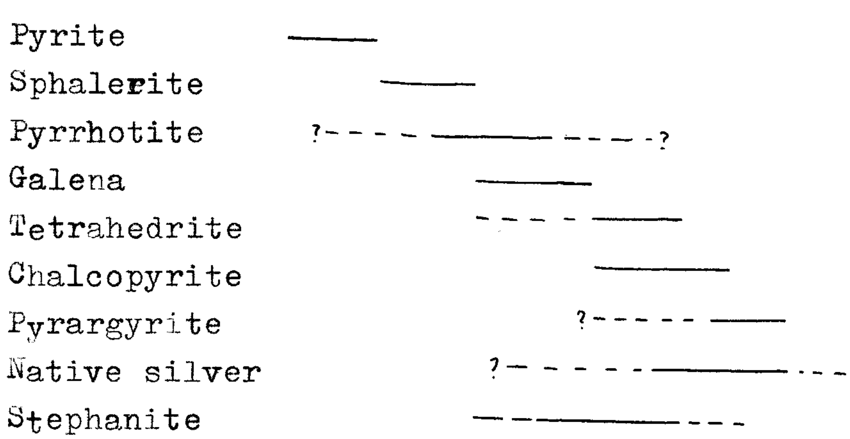
Though there are a few specks and veinlets of native silver in the sphalerite, as in Section 5, generally the silver minerals are confined to the galena or are isolated in the quartz or calcite gangue. The relative absence of them from the sphalerite is economically highly desirable. Comparatively coarse grinding (100 mesh?) will release the bulk of the silver-bearing material.

Paragenesis:

This has been discussed in more detail in the description of textures, but may be summarized as follows:

Brecciation of the country rock allowed the access of hypogene mineralizing fluids which replaced both the siliceous, calcareous and chloritic breccia matrix and the fractured quartz itself. Pyrite was deposited first, closely followed by sphalerite. Galena replaced sphalerite and was itself replaced by tetrahedrite, chalcopyrite, pyrargyrite and native silver, probably in that order, corresponding perhaps with the drop in temperature of the mineralizing fluids. Stephanite exsolved from the galena before the latter was replaced by tetrahedrite, which sometimes truncates blebs of stephanite. There is some doubt about the position of the native silver in the sequence, in view of its textural relationships with tetrahedrite as in Section 5.

The following diagram represents the likely paragenetic sequence:



References:

B.C. Minister of Mines Annual Reports, 1933-56
B.C. Department of Mines Bulletin #20, part III (page 13)
Warren, H.V. and Watson, K. de P, 1937, Economic Geology v.32, p.826ff. "A pyrrhotite-ruby silver deposit in B.C.".
McNaughton, D.H., 1945, - Greenwood-Phoenix area, B.C. - G.S.C. Prelim. Paper #45-20

PLATES

Symbols:
g - gangue minerals
ga - galena
sp - sphalerite
py - pyrite
pyr - pyrrhotite
ch - chalcopyrite
t - tetrahedrite
st - stephanite
pa - pyrargyrite

refers to number of polished section.

The scale is a close approximation only.

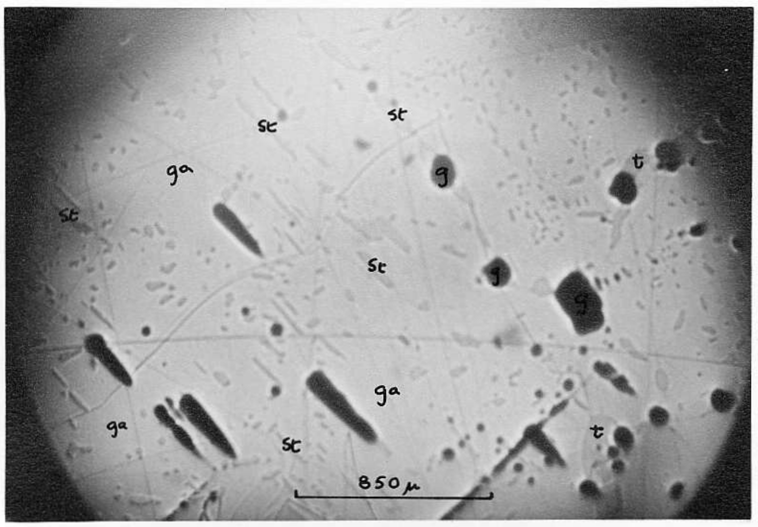


Plate 1

#2

Plate 2

#3

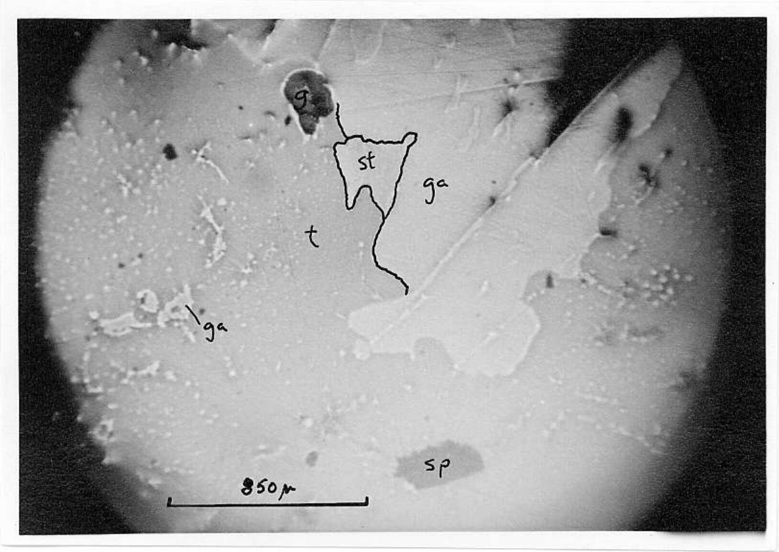


Plate 3

#3

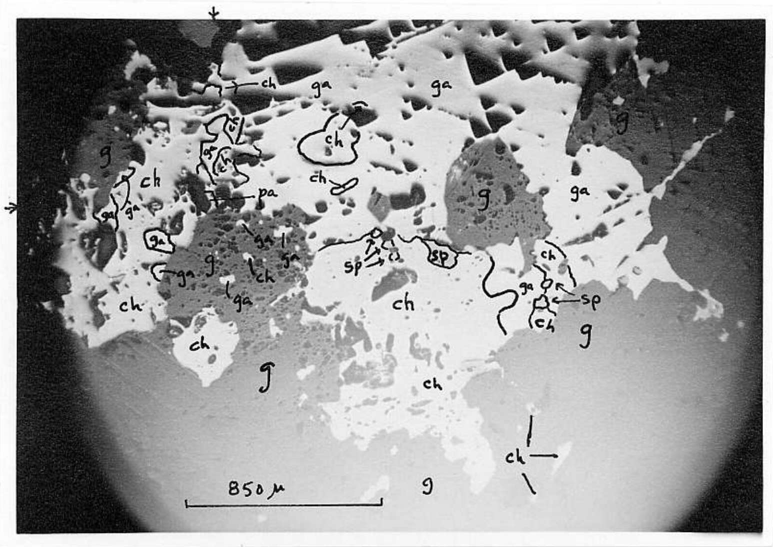


Plate 4

#4

Plate 5

#5

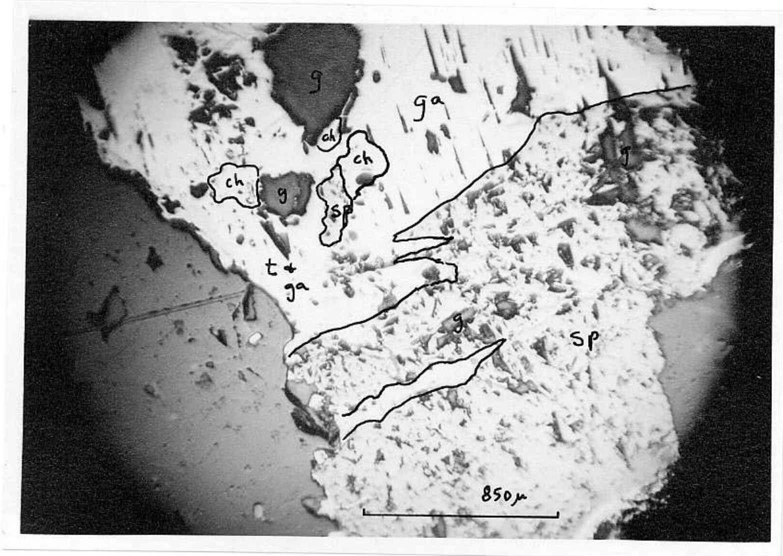


Plate 6
#5

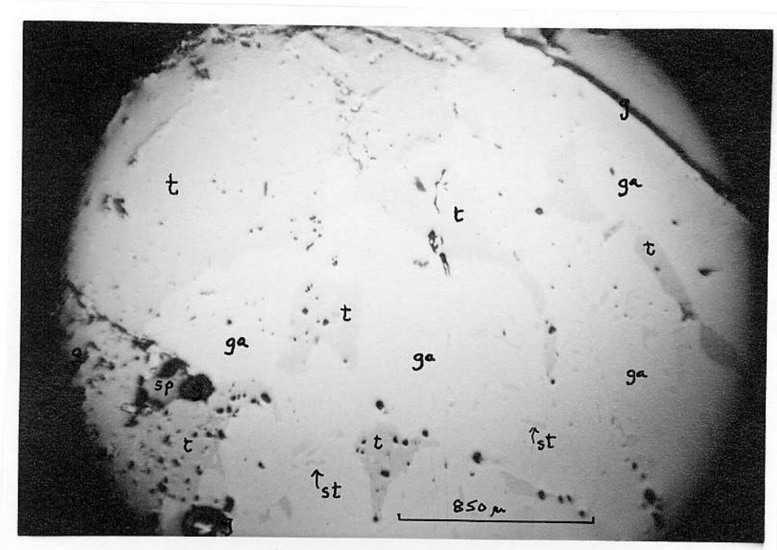


Plate 7
#6

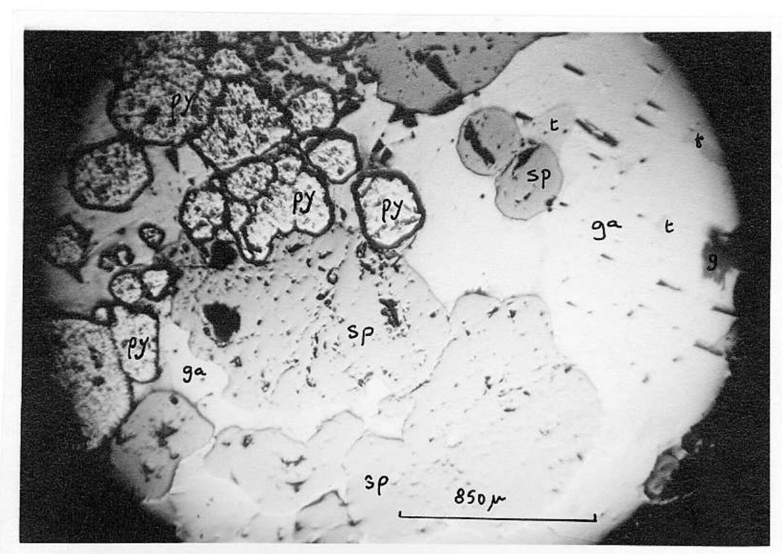


Plate 8
#7

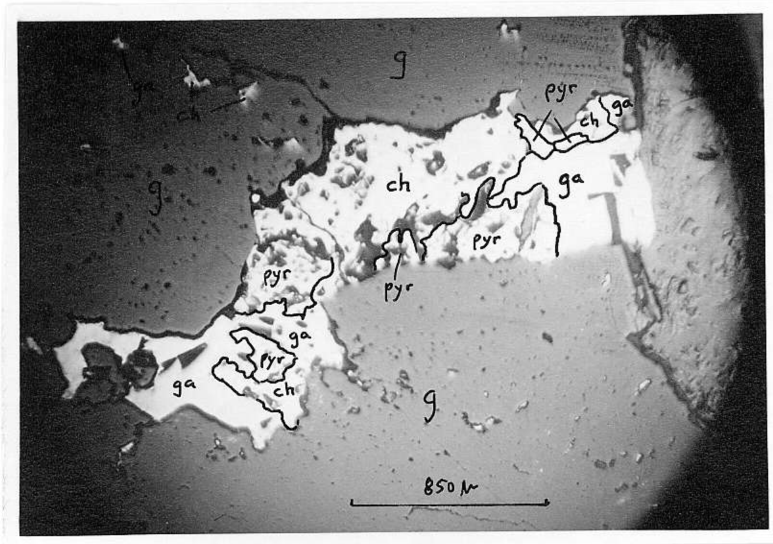


Plate 9
#8

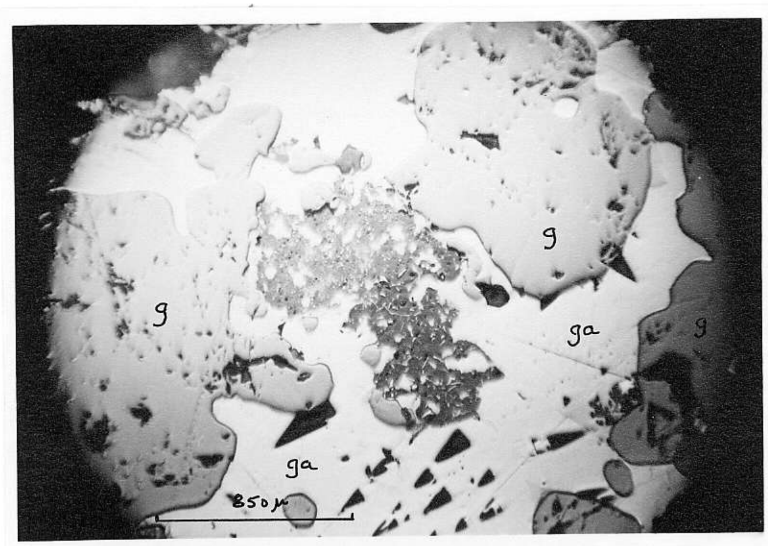


Plate 10
#8

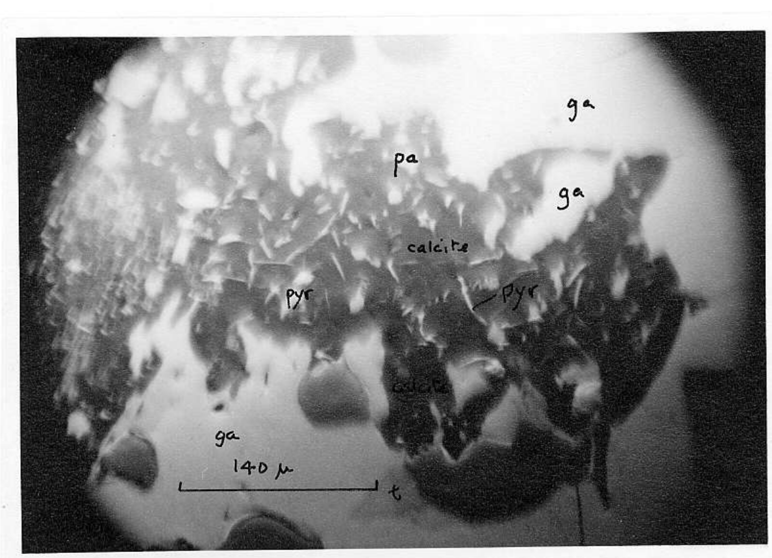


Plate 11
#8
(High power)