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MINERALOGRAPHY REPORT

PROVIDENCE MINE

BOUNDARY DISTRICT

BRITISH COLUMBIA

Geology 409

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writer.

## Introduction

This paper is principally concerned with the mineralogy of the gold-silver-lead-zinc ores of the Providence Mine, Boundary District, British Columbia. Brief mention is made of production, general geology, and other features in so far as they are determinable, and the paper ends with a necessarily brief bibliography.

## Location

The Providence Mine is located about one and one-half miles north of the town of Greenwood in South Central British Columbia and about eight miles north of the International Boundary. Approximate latitude-longitude coordinates are  $49^{\circ}06'$  N and  $118^{\circ}41'$  W.

## Production and History

The following data in regard to operation and production is derived from the British Columbia Minister of Mines Annual Reports for several different years.

The mine has been operated at irregular intervals and by various owners and lessees since 1897. Because it has not been particularly productive and because there is no prospect of important future activity operators have not

prepared mine maps or cross sections.

Whereas no data is available as to the extent of underground workings an indirect idea of size might be derived by considering the major equipment on the property (1953). This includes a 30 H.P. shaft hoist motor, 40 H.P. air compressor, and a 5 H.P. pump motor at the bottom of the shaft. A 5 H.P. motor is available for shaftwork. Much of the electrical equipment was installed in 1918 and considerable deterioration since then has taken place. In 1953 the operators were advised to modernize and repair this defective equipment.

In 1951 the owner was W. Madden, but whether the mine has come under new ownership since is not known to the writer. Yearly references are rather meager but in the following paragraphs is a brief resume of activity.

In 1937 it was operated for 365 days by an average of 16 men. No production figures are given. During 1943 W.E. McArthur of Greenwood operated the property continuously with a crew of 5 to 7 men. A total of 427 tons were mined and shipped to the Trail smelter, and this yielded 224 oz. of gold and 53,393 oz. of silver. Some lead and zinc were also produced but production figures are unavailable.

In 1951 more work was undertaken by lessees with two shipments of ore. The total production was 36 tons with the following gross-content: gold, 8 oz.; silver, 2,964 oz.; lead, 1,285 lbs.; and zinc, 1,112 lbs. In 1952

two small shipments were made totaling 14 tons. Metal content as follows: gold, 8 oz.; silver, 223 oz.; lead, 929 lbs.; and zinc, 805 lbs.

During 1953 work was done by lessees in different parts of the mine. No ore was shipped, although several tons removed during the development work were stored at the mine. Since this time there has been no activity.

As an indication of the mines financial productivity the total dividends paid between 1897 and following years are given: 1938, \$33,810; 1940, \$43,425; 1943, \$131, 824; and 1951, \$142,328.

#### General Geology

According to Warren and Watson (1937) the ore of the Providence mine occurs in a fissure cutting various Paleozoic (?) rocks. The rocks consist of augite porphyrites, agglomerates and porphyritic tuffs, all of which have been subjected to intense metamorphism. In places the Providence vein irregularly cuts masses of granodiorite, which are thought to be portions of the Greenwood Stock underlying the famous but now exhausted Phoenix Copper Camp. Seraphim (undated, unpublished manuscript) says "Intrusions (laramide) were accompanied by mineralization. Many small precious metal lodes were formed near the border of the Greenwood Stock." It is assumed that the Providence mineralization is of this type.

The vein itself is from 6 to 18 inches wide and is cut by numerous small faults, as well as by a few post mineral

dikes.

### Mineralogy

The mineralogy was studied first on the basis of about 15 hand specimens, both with hand lens and binocular microscope. Six specimens of representative rocks were made and mounted in bakelite containers for ease of study. About four polished sections of somewhat larger surface area, and temporarily mounted in clay were also used.

The following minerals, listed approximately in the order of abundance are those identified in polished and/or hand specimen.

#### Quartz

The quartz is usually microcrystalline, milky white and is veined and invaded by all of the other minerals with the probable exception of pyrite and arsenopyrite.

#### Calcite

The calcite is crystalline and milky white. It seems to be slightly darker than the quartz although this is not always apparent. The calcite seems to be occasionally filling fractures in the quartz, suggesting that its deposition continued on after the cessation of quartz deposition.

#### Sphalerite

The sphalerite is the most conspicuous metallic mineral present. There are rather extensive masses of reasonably pure sphalerite extending over perhaps an inch in hand

specimen. Portions of the sphalerite show inclusions of chalcopryrite (Plate 1, A), some oriented in a crystallographic direction, others showing no particular orientation. Large portions of sphalerite show no inclusions of any sort. The maximum chalcopryrite content might reach 5 per cent but usually is considerably less. Inclusions of strongly corroded pyrite crystals are common.

According to Warren and Watson (p. 827, 1937) a carefully picked sample of sphalerite was assayed and found to carry 7.82 oz. of silver per ton.

Where the sphalerite is in contact with galena, there is a definite penetration of, and surrounding of the sphalerite fragments. The sphalerite even occasionally reaches the state of near circularity, due to rounding of edges.

Also inclusions of galena and tetrahedrite were observed within the sphalerite, either occurring together or as independent inclusions. The contacts between the tetrahedrite, galena and sphalerite are sharp, smooth, regular curves. This suggests contemporaneous deposition, but does not prove it by any means, as Warren and Watson suggest (p. 828, 1937).

### Galena

Galena closely rivals sphalerite in abundance, both being important sulfides. It is reasonably homogeneous although it surrounds many minerals and is replacing some of them. Triangular cleavage pits are common, but no zonal



texture was observed. Included within the galena are sharp bounded inclusions of tetrahedrite and pyrargyrite (Plate 3, B). Rarely seen are minute inclusions of chalcopyrite averaging about ten microns in length.

### Pyrite

Pyrite is common and widespread. There is little doubt that it was the first sulfide to form because in many places the crystal outline is well preserved, presenting a straight crystal margin to surrounding minerals. Most of the pyrite grains however, are undergoing a replacement, particularly by sphalerite and galena which has left embayments and projections of these minerals in the pyrite. In one place at least, incipient atoll texture was observed. Replacement has frequently proceeded up fractures separating an original crystal into many divided, rounded fragments (Plate 3, B; Plate 2, B). In polished section two corroded crystals of pyrite were found containing cores of small quartz fragments. Warren and Watson (p. 827, 1937) observed a small particle of pyrite in quartz. These two facts, plus the observation that pyrite is the only mineral outside of arsenopyrite, not occurring in quartz fractures suggests that pyrite and quartz deposition was essentially simultaneous.

### Chalcopyrite

Chalcopyrite, as previously mentioned, occurs as an apparent exsolution mineral with sphalerite, but large portions of sphalerite are free of chalcopyrite. Very frequently

the chalcopyrite appears to be completely emancipated from the sphalerite and associated with most of the other minerals, and like sphalerite is corroding pyrite crystals (Plate 2, B). Certain areas of chalcopyrite, although very small do contain at the margins a few small inclusions of sphalerite, the common orientation of the sphalerite fragments suggesting a replacement origin.

### Pyrargyrite

Pyrargyrite while not quantitatively as important as some other minerals, is rather universally distributed through the ore. It occurs usually in the form of irregular masses and worm like growths associated most commonly with the tetrahedrite and galena. Frequently it is found in contact with chalcopyrite, sometimes with a highly irregular border suggesting an intergrowth of some sort. The size of the pyrargyrite masses in the galena is quite variable, the largest exceeding 100 microns.

Frequently native silver is intimately associated with the pyrargyrite but quantitatively speaking the pyrargyrite is 10 or more times as common.

### Tetrahedrite

Tetrahedrite is a minor mineral, seen only in polished sections and occurring almost exclusively as inclusions in galena and sphalerite (Plate 3, B), averaging 80 to 150 microns. Most of the inclusions lie near the galena-sphalerite or galena-pyrite borders, suggesting more or less successful

solid diffusion. The tetrahedrite inclusions range from small, essentially circular masses with a diameter of around 75 microns to highly crenulated masses that may reach 800 microns in length. Whereas tetrahedrite and sphalerite do not form exsolution textures a replacement texture is probably indicated.

### Arsenopyrite

The arsenopyrite occurs in varying quantities, some sections showing considerable amounts, others showing none. Most of the arsenopyrite is associated with pyrite and like the pyrite has been replaced by later minerals. The largest masses of arsenopyrite, like pyrite, reach an upper size limit of about 1000 microns. Size ranges downward probably to sub-microscopic level.

A more "textbook style" of arsenopyrite is in the form of small (perhaps 50 microns) rhombohedral crystals. These usually show no evidence of replacement and maintain their distinctive form against every mineral including quartz (Plate 3, A).

### Native Silver

Silver is definitely seen only in polished section and is usually associated with the pyrargyrite. The individual silver masses are very small though occasionally somewhat larger worm-like growths occur in the pyrargyrite (Plate 2, A). Because of this small size micro-chemical tests are not possible and etch tests are most unsatisfactory.

Immediately after polishing the silver appears to be a brilliant creamy white though after a little exposure it takes on a pinkish cast. Its hardness is around B and it is definitely isotropic.

### Bornite

Bornite is a very minor mineral seen only in a few spots in hand specimen, and is always associated with the chalcopyrite. It is exceedingly finely disseminated and probably represents either a supergene alteration of the chalcopyrite or a mineral contemporaneously deposited with the chalcopyrite.

### Argentite

Argentite, also very minor, is not seen in polished section. Its occurrence is restricted to fracture surfaces, where it has been plastered on like a very thin layer of clay. In fact it is so thin and so sectile that it can easily be peeled off. It has a dull metallic luster, hardness of around B and gives a strong, definite, silver micro-chemical test.

### Stromeyerite

Stromeyerite was found in exactly the same environment as argentite, i.e., plastered on fracture and hence not showing in polished section. Physically it appears as a thin, massive, lead gray mineral. It is somewhat flexible but soon breaks if the bending is continued.

The stromeyerite defied micro-chemical analysis because of a test for both antimony and lead, as well as a very unsatisfactory test for silver. Because no mineral of

this composition fulfilled the physical properties observed, an X-ray powder photograph was made. This test indicated stromeyerite, a copper-silver sulfide.

After the mineral had been determined by X-ray the writer again tried micro-chemical tests. As before the results were useless since only a very poor silver test was indicated and absolutely no copper was indicated. This forcibly brought to the writers attention the occasional uselessness and downright misleading information which can be derived via micro-chemical tests.

The environment of the stromeyerite indicates rather conclusively that it is one of the later or perhaps last mineral to form. Dana (p. 420, 4th Ed.) says "stromeyerite. . . . is usually formed by the reaction of descending silver solutions upon bornite, with which it is often intimately intergrown."

This interpretation of g<sup>N</sup>esis is questioned for this occurrence because of the striking lack of supergene minerals. True some bornite is present, as well as some possible supergene argentite, but bornite is not common and might well be the result of contemporaneous deposition with chalcopyrite. This latter is the view suspected to be true by the present writer. This occurrence is of some interest since it is only the second time that stromeyerite has been found in British Columbia.

#### Chlorite

A green, fibrous to massive chlorite apparently

occurs quite commonly bordering the veins. The writer suggests that it was formed as the result of the breakdown and subsequent diffusion of earlier formed mafic constituents. The metamorphism accompanying the mineralization was of a type that increased the silication of the immediate area. Under these conditions biotite, amphiboles, and pyroxenes would break down and their constituent ions migrate to the border of activity where they would be precipitated as a mafic mineral stable under the prevailing conditions, i.e. chlorite.

Apparently the silver values of this ore occur in several different minerals though the relative proportion in each is unknown. Silver definitely occurs in the sphalerite, pyrargyrite, argentite, stromeyerite and native silver. It may also occur and probably does in the tetrahedrite and galena.

No gold minerals were found. Whether or not gold occurs in this suite of ores is unknown because no assays were made but if it does it is probably in solid solution with native silver and possibly in the pyrite.

No pyrrhotite was found in this suite, a rather notable divergence from the occurrence described by Warren and Watson.

### Paragenesis

The mineralogy is of a rather simple type but the lack of sufficient distinctive textural relations precludes the possibility of formulating exact genetic relations. Some

features are open to interpretation. For example the writer is adverse to Warrens<sup>CONTEINION</sup> (p. 828, 1937) that smooth regular curves indicate contemporaneous deposition. That may be the case, but boundary relations are certainly not conclusive, and it is somewhat credulous to assume that they are.

Below is briefly stated the writer's interpretation of genesis in the light of textural features.

The deposit suggests a fracture filling with quartz, calcite, pyrite, and arsenopyrite essentially contemporaneous. Because the calcite is occasionally found filling fractures in the quartz its deposition probably continued somewhat longer. All of the remaining minerals in the sequence are found in calcite fractures so it is definitely dated as being an early mineral. Minor brecciation before commencement of final sulfide deposition is indicated by the several small fractured quartz nuclei found with several pyrite crystals. Apparently after calcite formation another very minor fracturing resulted in cracks in the calcite later followed by sulfide mineralization. It is probable that this last fracturing took place after termination of pyrite-arsenopyrite deposition since neither of these is seen in the fractures.

Following next came the major phase of sphalerite deposition. Some of the sphalerite precipitated shows exsolution textures with chalcopyrite, but other areas of sphalerite show no such texture. The sphalerite like other successively deposited minerals, corrodes and replaces minerals that

proceeded it, in this case replacement of pyrite.

Before the end of sphalerite deposition a small quantity of tetrahedrite was precipitated by quantitatively in rather small amounts. Chalcopyrite and bornite followed soon thereafter. It should be remembered that the writer is assuming the bornite is primary, as he feels greater quantities of bornite are required if it is to be assigned to a supergene origin. In any event the problem of a hypogene or supergene origin for bornite has no critical bearing on the general sequence of mineral deposition.

The next major phase was the precipitation of galena with exsolution of pyrargyrite and tetrahedrite. The galena actively corroded all previous minerals and some fragments of sphalerite have assumed near circularity. Much of the tetrahedrite managed by diffusion to migrate to the borders of the galena grains, but the pyrargyrite is more or less equitably distributed.

Probably at this time the temperature had dropped to the vicinity of 300°C with the native silver in the process of formation. Although it is of minor amount silver actively replaced pyrargyrite and to a lesser extent galena.

About this time a minor fracturing occurred with the last two sulfides being deposited. Argentite and stromeyerite were precipitated on the vein walls as thin films, but apparently had no tendency to replace pre-existing minerals.

The genetic position of chlorite is a bit hazy though it was probably being formed during most of the period



of mineralization. At any rate some pyrargyrite apparently associated with the chlorite was involved in the minor post-mineralization fracturing that took place. In a few specimens the chlorite is definitely slickensided and some pyrargyrite has been smeared out by this same movement.

Whether the period of fracturing which produced this slickensiding is the same one affecting the main vein, and which was immediately followed by argentite-stromeyerite deposition is conjectural.

Another genetic interpretation which suggests itself is to assume that the bornite, native silver, argentite, and stromeyerite are supergene. In other words later ground water activity deposited the silver, altered the chalcopyrite and terminated with deposition of argentite and stromeyerite. Either alternative explanation seems to satisfy the evidence so the writer would prefer not to make any definite commitments.

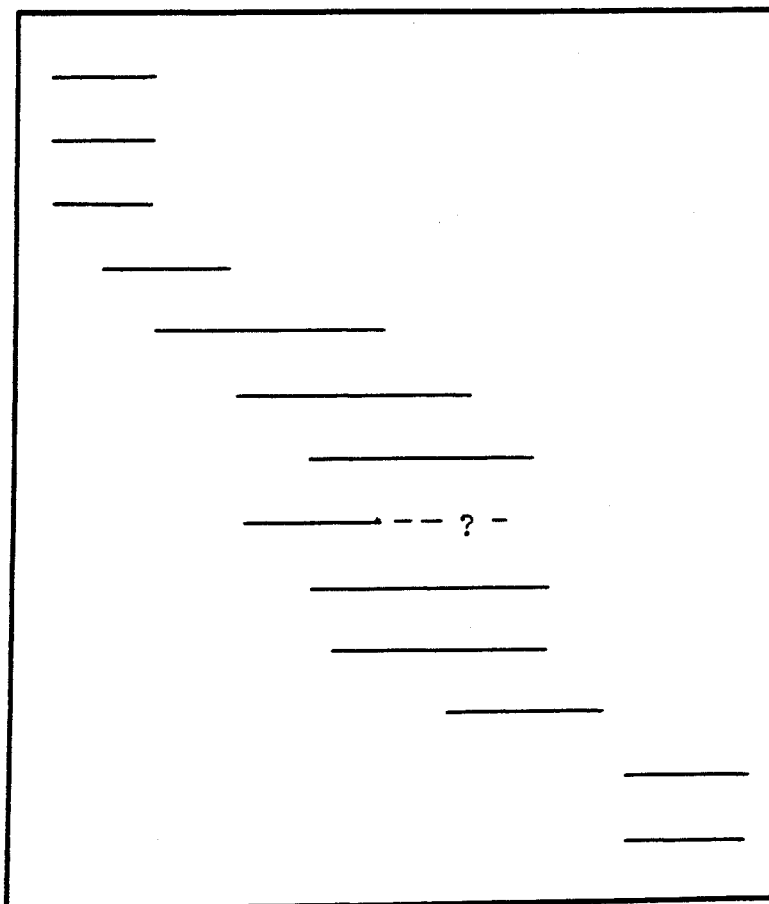
The diagram following summarizes paragenetic sequence as it would appear if the minerals are all assumed to be primary. If the above four minerals are in actuality secondary then bornite should be moved to the right, in approximately the position marked by the dotted line.

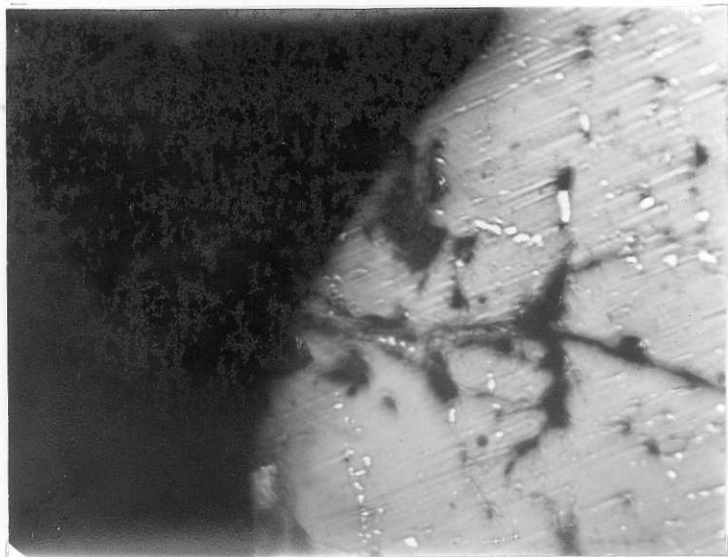
In brief then, the Providence deposit represents an essentially conventional hydrothermal, mesothermal orebody. The essential control was structural, probably along a fracture or fault zone. Minor fracturing and faulting has occurred in post mineralization times.

No definite conclusion has been reached as to whether the latest minerals are hypogene or supergene. A primary origin is suggested by the relatively small quantities of bornite and by the fact all these minerals have occurred in other deposits as hypogene. Conversely a secondary origin is suggested by the obvious low temperatures of deposition displayed by Argentite and Stromeyerite, plus the complete lack of alteration by these minerals. In addition these later minerals commonly occur as the result of secondary activity.

## PARAGENESIS IN SYNOPTIC FORM

Quartz  
 Pyrite  
 Arsenopyrite  
 Calcite  
 Sphalerite  
 Chalcopyrite  
 Tetrahedrite  
 Bornite  
 Galena  
 Pyrargyrite  
 Native Silver  
 Argentite  
 Stromeyerite



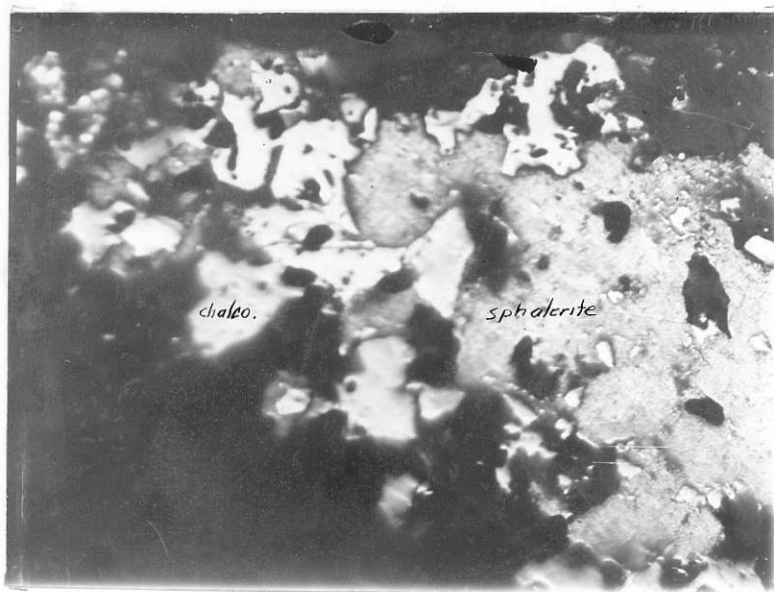


Exsolution of chalcopyrite in sphalerite.

Occasional orientation in crystallographic directions.

Magnification 120

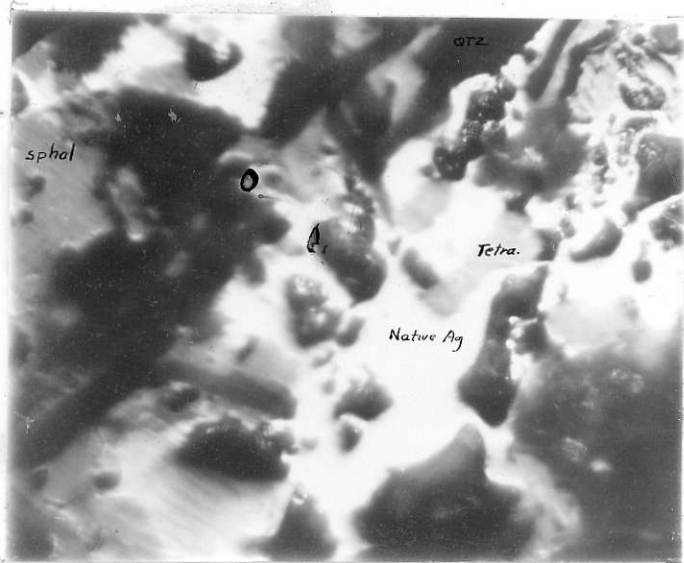
A



Chalcopyrite in process of replacing sphalerite.

Magnification 120

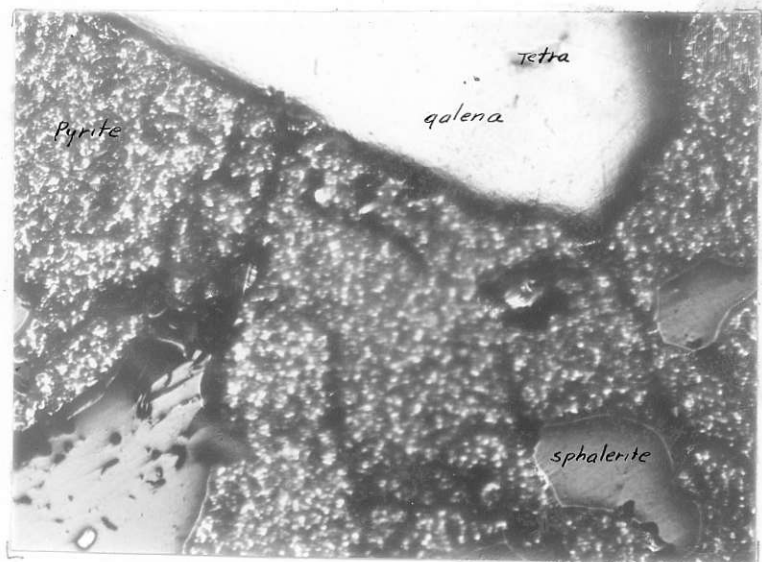
B



Native Silver replacing  
pyrrargyrite. Dark  
gray material is  
sphalerite.

Magnification 350

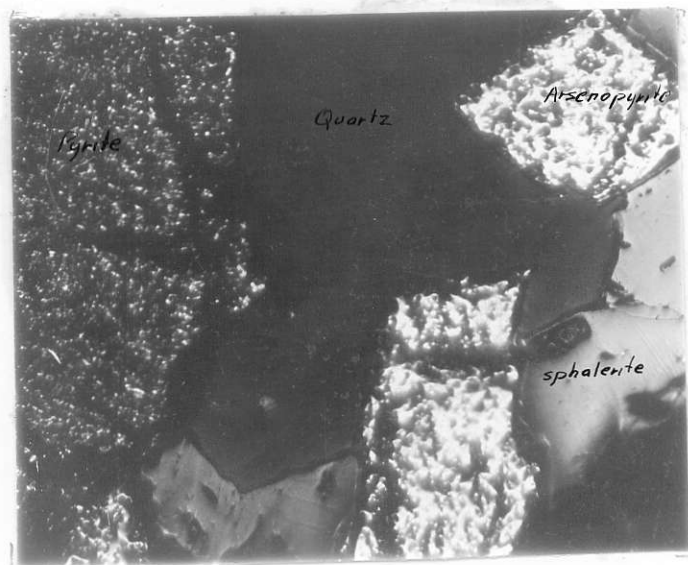
A



Pyrite in process of  
being replaced by  
galena, sphalerite  
and tetrahedrite.

Magnification 120

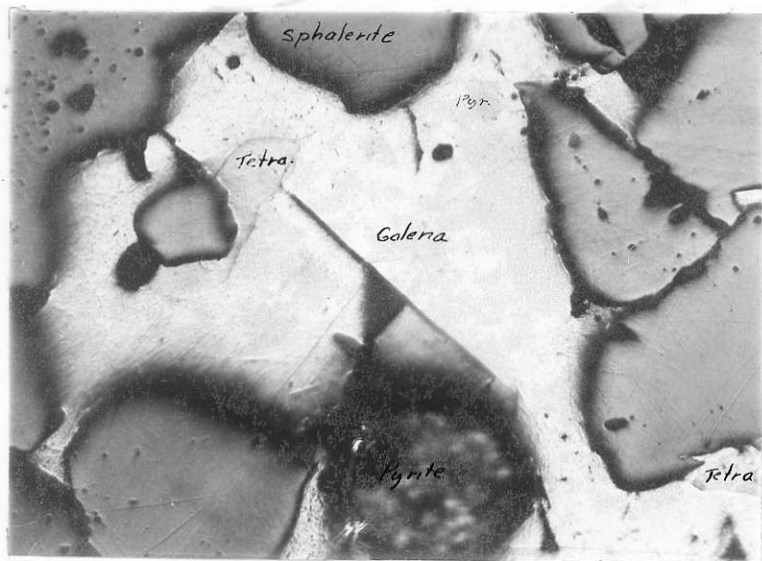
B



Crystals of arsenopyrite maintaining their form against quartz and sphalerite.

Magnification 120

A



Exsolution of tetrahedrite and pyrargyrite in galena. Notice nearly circular pyrite and sphalerite fragments.

B

BIBLIOGRAPHY

- Dana, E.S.; "Textbook of Mineralogy;" John Wiley and Sons, Inc.  
New York, 4th Ed.
- Edwards, A.B.; "Textures of the Ore Minerals;" Australasian  
Institute of Mining and Metallurgy; Melbourne, 1954.
- Seraphim, R.; "The Copper Deposits of the Boundary District,  
B.C.;" Undated, Unpublished Manuscript.
- Short, M.N.; "Microscopic Determination of the ore Minerals;"  
U.S.G.S. Bulletin 914; Washington, D.C., 1940.
- Vytenbogardt, W.; "Tables for Microscopic Identification of  
Ore Minerals;" Princeton University Press, 1951.
- Warren, H.V. and Watson, K. De P.; " A Pyrrhotite--Ruby Silver  
Occurrence in British Columbia; Economic Geology, Vol. 32;  
no 6, pp. 826-831, 1937.
- Minister of Mines Annual Report, Province of British Columbia,  
Victoria, B.C.; For the following years: 1937, 1943, 1944,  
1951, 1952, 1953.