English not too good in places
Stephanite & stannite require
x ray confirmation.

A MINERALOGRAPHIC STUDY OF ATLIN RUFFNER ORES

by

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A report submitted in accordance with
the requirements of Geology 409.

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PHOTOMICROGRAPHS

SUMMARY

The Atlin Ruffner property is located in the Atlin Mining Division of British Columbia. The ore deposits occur as a series of veins in faulted lamprophyre dykes. The ore is principally a base metal sulphide of Lead-Zinc*Silver. The following minerals were identified in the ore: arsenopyrite, pyrrhotite, pyrite, sphalerite, chalcopyrite, galena, gold, tetrahedrite, pyrargyrite, stephanite and stannite. to be checked. The gangue is predominately quartz and silicified wall rock, with some calcite and siderite. The deposit is classified as a mesothermal type of deposit.

INTRODUCTION

Location and History

The Atlin Ruffner property is located in the Atlin Mining Division of British Columbia. The district is situated on the east side of the Coast Range Mountains in the northwest corner of the province, just south of the Yukon-B.C. boundary. The property itself is located on Vaughan Mountain in the vicinity of Fourth of July Creek, a distance of about 14 miles northeast of the town of Atlin. The area is easily accessible by a branch road extending south from the Alaska Highway.

The Atlin Ruffner group recieved much attention during the 1920's and early 1930's. Development work on the property first started in 1921. The group was owned and operated by the Atlin Silver-Lead Mines Ltd. Considerable drifting and trenching was carried out, but no large scale mining. Work was chiefly confined to exploration. Small tonnages of ore were shipped to Tacoma and Trail; the tonnage amounted to less than 300 tons. Primarily the ore is one of lead, with high values in silver. Reported silver values have been as high as 700 oz. per ton, but the average appeared to be much lower. The following are reported assay values from two shipments, one of 30 tons and one of 11 tons.

Gold	0.16 oz./ton	0.11 oz./ton
Silver	75.70 oz./ton	193.95 oz./ton
Lead	12.40 %	3.10%
Zinc	29.25 %	7.7 %

General Geology and Ore Deposits

The geologic environment of VaughAN Mountain is granitic. The granitic rocks range in composition from granite to quartz diorite to diorite. In many places the granite is porphyritic. The granitic rocks are cut by numerous dykes, both acid and basic types. The basic dykes are hornblende lamprophyres and appear to be older in age than the acidic type. The acidic dykes are aplites, and are generally smaller than the lamprophyres.

The lamprophyre dykes are the home of the ore deposits, whereas the aplite dykes are barren. The laprophyre dykes formed lines of weakness and have been intensely sheared and crushed by subsequent crustal movements. The mineral bearing solutions following along these shear zones filled fissures, replaced crushed rock, and cemented rock fragments with quartz, calcite and ore minerals. The ore occurs in parallel bands, bunches and small veinlets within the altered rock. Thus the mineralized dykes represent veins. The veins vary in width from a few to many feet, the average being approximately six feet. In strike length the veins are reported to extend as much as 5,000 feet. The veins have a general northeasterly strike and dip at moderately high angles to the northwest.

Due to the loose ground-up nature of the dykes, and the ease with which the laprophyres weather, intense weathering and oxidation occurs on all the veins. The weathered material consists of limonite, sand, and "ribs" of mineralized quartz. The oxidation has created a zone of secondary enrichment. The depth of oxidation is relatively deep, and has been a problem in explortation. The problem being to get below the zone of oxidation and valuating the primary sulphides.

Object of this Report

The chief aim of this report is to determine the minerals present, describe their occurence and relationships, determine the grain size of the valuble minerals, and to determine the paragenetic sequence. A further aim in undertaking a study of this ore was to attempt to isolate and identify a mineral reported to be present in the ore. T.J. Donaldson (1953) described a mineral whose properties suggested it might be argyrodite ($4Ag_2S.GeS_2$), but positive identification was impossible. In the suite of specimens examined by the writer, no trace of the mineral, or what be the mineral was found. The following is a list of minerals determined by Donaldson, from a separate suite of specimens from the Ruffner group.

Ore Minerals	Gangue
galena	quartz
sphalerite	calcite
pyrite	ankerite
marcasite	
chalcopyrite	
arsenopyrite	
tetrahedrite	
pyrargyrite	
pyrrhotite	

Acknowledgments

The writer extends his sincere thanks to Dr. R.M. Thompson, and Mr. V. Papiezek for their untiring assistance and guidance.

Thanks are also extended to Mr. J.A. Donnan for technical advice and assistance in preparing polished sections.

MEGASCOPIC DESCRIPTIONS

The suite of specimens examined by the writer was supplied by Dr. A. Aho. The suite consists of approximately 15 specimens, varying in character to some degree. The following is a megascopic description of typical specimens found in the suite.

Type 1 - Coarse grained galena.

Specimens of this type consist of aggregates of coarsely crystalline galena in a gangue of quartz. Galena comprises greater than 60 % of the specimens. The galena occurs in bunches of anhedral cubes, averaging ¼" on edge, some being as large as ½" on edge. Associated with galena are small amounts of chalcopyrite and sphalerite occuring in irregular patches. The gangue is fine grained, almost sacharoidal, smoky-white quartz. Very little calcite is present. Many tabular or sheet-like vugs are present. These vugs commonly occur along the sides of galena bunches, separating the galena from the quartz. The openings of the vugs are narrow, generally less than ¼" in width. Lining the vugs are minute "one ended" quartz crystals having a comb texture. It was noted in the microscopic study, specimens of this type contain relatively abundant gold and ruby silver, and pyrrhotite.

Type 2 - Massive Galena

The galena in this type of specimen is poorly crystallised, and few cubes can be seen. The specimens of this type consist of solid galena with apparently no other ore minerals present. Very little gangue is present, but what gangue is present occurs as tiny quartz stringers cutting through the galena. Microscopic study indicated that specimens of this type contain little ruby silver, and no visible gold.

Type 3 - Brecciated Specimens.

From the description of the veins given in the B.C. Minister of Mines reports, this type of specimen would seem to be typical of the ore found in many of the veins. The specimen has a brecciated texture. It consists of angular rock fragments, commonly 1 inch in size, cemented and partly replaced by gangue and ore minerals. The fragments are green, and whitish where they have been partly silicified. Some of the smaller fragments have been altered to a chloritic material and occur as small patches throughout the ore. Quartz is abundant and occurs as dirty white masses impregnated throughout the specimen. Quartz and altered wall rock form the bulk of the gangue. Siderite (?) (or ankerite), occurs as yellow-brown crystals in small stringers throughout the specimen. Small amounts of white, poorly crystalline calcite is also present. The ore minerals compose greater than 40 % of the specimen. Arsenopyrite and galena are the most abundant sulphides present. The aresenopyrite is fine grained and occurs in patches and disseminations. The galena is also fine grained, individual cubes, where visible, are less than 1/8" on edge. The galena occurs in bunches and disseminated grains throughout the other ore minerals and gangue. Sphalerite is also relatively abundant in the specimen. It has a very dark, almost black, color and an adamantine lustre. Its occurence is similar to that of galena. Chalcopyrite and pyrite are present in lesser amounts and occur in irregular patches in the ore.

Type 4 - Fine grained specimens.

Specimens of this type consist of massive clear quartz impregnated with small grains of sphalerite, arsenopyrite, and pyrite. The sulphides comprise about 30 % of the specimen and scattered uniformily throughout the quartz. Some specimens have a banded appearance, the bands being about ¼" wide and composed of arsenopyrite.

Type 5 - Ribbon quartz

Specimens of this type consist of smoky quartz having a ribbon texture. The bands are almost paper thin and appear to be filled with greenish rock material. Pyrite and galena occur in roughly parallel bands (½"), and as disseminated grains.

Molybdenite

One specimen of quartz containing a patch of molybdenite was present in the suite. However, this mineral was not found in any of the polished sections examined.

Fluorite

Two specimens of quartz containing green fluorite crystals were also present in the suite. However, it is unlikely the fluorite or molybdenite were taken from the veins on the property.

Why not?

Gossan

The gossan consists of hard, compact limonite, dark brown to buff in color. Numerous "skeletons" of pyrite or galena crystals are present in the compact limonite. The limonite also occurs as a loose, incoherent yellowish powder, coating small vugs and cracks.

Wall Rock Alteration

Typical wall rock alteration of the property consists of altered "granite". It is a dirty green looking rock having an isotropic texture. A hasty examination of a thin section of this specimen showed it was made up principally of quartz, chlorite, white mica and apatite.

MICROSCOPIC EXAMINATION

Microscopic examination of the ore consisted of the study of 12 polished sections, using methods outlined by M.N. Short (1948), and identification tables compiled by W. Uytenbogaardt (1951). Lack of time did not allow for x-ray analyses of minerals not definitely identified by microscopic means.

Gangue

The chief gangue mineral is quartz, and it was deposited in at least two periods of time. The first period of quartz deposition occured after the initial fracturing of the host rock. This quartz is generally clear and occurs in euhedral to subhedral crystals. However, some of this early quartz is not well crystallized, but occurs as massive grains and patches. In all probability this type of quartz represents silicified pieces of country rock.

A second period of quartz deposition is indicated by narrow quartz stringers and veinlets transecting sulphide minerals and older quartz. There apparently was a refracturing of the rock and the early deposited quartz and sulphides, producing fissures in which the younger quartz deposited. Plate II shows a fractured pyrite grain, the fractures being filled with the younger quartz.

Small stringers of a gangue mineral showing a brown coloration under crossed nicols probably represents the siderite(?) observed in the hand specimens. This carbonate and calcite occur in narrow veinlets transecting sulphide grains, They probably were the last minerals to deposit in the ore.

A secondary lead mineral, anglesite or cerussite, also occurs in the ore. This mineral occurs principally along cleavage planes of galena as narrow veinlets, less than 100 microns in width.

Ore Minerals

The following is a list of the minerals determined occuring in the ore. Each mineral is described individually giving its mode of occurrence, grain size, diagnostic textures, and relationship to the other minerals with which it occurs.

Sulphides

Arsenopyrite $FeS_2.FeAs_2$
Pyrrhotite $Fe_{1-x}S$
Pyrite FeS_2
Sphalerite ZnS
Chalcopyrite $Cu_2S.Fe_2S_3$
Galena PbS

Sulpho Salts

Tetrahedrite $5Cu_2S.2(Cu,Fe)S.2Sb_2S_3$
Pyrargyrite $3Ag_2S.Sb_2S_3$
Stephanite $5Ag_2S.Sb_2S_3$
Stannite $Cu_2S.FeS.SnS_2$

Native Element

Gold

Arsenopyrite

Arsenopyrite appears to be one of the first metallic minerals to deposit in the ore. It commonly occurs in rhomb-shaped,gtriangular, and lath-like grains varying is size from 10's to a few hundred microns. The mineral often occurs in quartz and this association suggests contemoporaneous deposition of the two. Evidence of arsenopyrite replacing other minerals is absent in all the sections examined. However evidence of other minerals replacing arsenopyrite was present. Plate I illustrates two such cases. The first photomicrograph shows pyrargyrite replacing a rhombic grain of arsenopyrite. It is unlikely that the pyrargyrite replaced the arsenopyrite, but rather the embayment was created by galena, ? which in turn was replaced by the ruby silver. The second photomicrograph shows deeply corroded borders of an arsenopyrite grain being replaced by sphalerite. No visible gold could be seen associated with the arsenopyrite. The mineral is relatively abundant, and in some sections comprises upto 15 % of the metallic minerals present.

Pyrrhotite

The abundance of pyrrhotite in the ore is relatively small. It comprises less than 2 % of the minerals present. Of the sections examined, section # 9 contained the greatest abundance of this mineral. The pyrrhotite occurs as massive, irregularly shaped grains sitting in a groundmass of galena. The majority of the grains are from 200 to 500 microns in size, but a few are only a few ten's of microns long.. Most of the pyrrhotite grains appear to be remanents of pre-exsisting larger grains which have been replaced by other minerals. Plate II shows a grain of pyrrhotite almost completely dissected by projections of galena. Evidence indicating the exact time of deposition of the pyrrhotite is lacking, but what evidence is present indicates the mineral deposited before galena and sphalerite. Since pyrrhotite is a high temperature mineral, it is probable that it deposited early in the history of the ore. It may have deposited contemporaneously with arsenopyrite.

Pyrite

Pyrite is relatively abundant in some sections, but scarce in others. Section # 2 is composed almost entirely of pyrite. The mineral occurs in a coarse, anhedral granular mass, with individual grains averaging 200 microns in diameter. Numerous grains of pyrite have been highly fractured, possibly by subsequent movements along a shear zone. These fractures are parallel in arrangement and are filled with quartz, and in one or two instances by sphalerite (?), (see Plate II). It was noted that broken grains of pyrite occured in sections having a high sphalerite content (section # 8). Sections composed predominately of galena contain very little pyrite. The writer also observed that in such sections, that ~~in such sections~~, if arsenopyrite was present then small grains of pyrite also occured. Thus there appears to be a close relationship in the time of deposition of the two minerals. Several grains of pyrite show an anomolous anisotropism, however the texture does not suggest the presence of marcasite. No visible gold was observed in the pyrite, but if present it may have gone undetected due to a poor polish.

Sphalerite

Sphalerite is one of the more abundant base metal sulphides present; it represents about 20 % of the ore minerals. The mineral occurs as large irregular masses (section # 1), several millimeters in size, intermingled with quartz, small amounts of galena, and chalcopyrite. The mineral has a deep reddish-brown internal feflection and commonly shows lamellar twinning. The dark color observed in a hand specimen, and the deep internal reflection is probably indicative of a high iron content in the mineral.

Sphalerite appears to be the first of the base metal sulphides to deposit. Several sections indicate deposition of the sphalerite took place after the deposition of arsenopyrite and pyrite. Plate IV shows sphalerite replacing, or extending along boundaries between pyrite grains. Some pyrite grains are completely transected by narrow veinlets of sphalerite.

Chalcopyrite

Chalcopyrite is relatively abundant in some sections, but absent in others. It comprises about 5 % of the ore minerals present. The bulk of the chalcopyrite is intimately associated with sphalerite, both in space and time. The chalcopyrite commonly occurs as varied shaped bodies ranging in size from a few to several hundred microns across, randomly oriented in sphalerite. The grain boundaries are smooth and suggest contemporaneous deposition. Much of the chalcopyrite occuring in the sphalerite is the result of exsolution, thus definitely indicating simultaneous deposition. Plate III illustrates an "emulsion" or "mottled" texture of chalcopyrite exsolution bodies in sphalerite. The arrangement of the chalcopyrite bodies is mostly seriate, but some of the smaller bodies tend to be oriented in straight lines. This orientation may be governed by a crystallographic or cleavage direction. Chalcopyrite veinlets cutting pyrite (see Plate III) definitely indicates the chalcopyrite deposited after the pyrite. The occurence of chalcopyrite veinlets in pyrite is very similar to that of sphalerite; both occur in the same section, but one does not replace the other.

Evidence of a late period of chalcopyrite deposition is present in some sections. This period of deposition appears to be closely associ-

associated with pyrargyrite. Narrow veinlets containing both chalcopyrite and pyrargyrite occur along cleavage planes in galena (see Plate VI). The chalcopyrite does not appear to be as selective in replacing the galena as is the pyrargyrite. The pyrargyrite often replaces large areas of galena, but the chalcopyrite appears to be confined to the cleavage planes.

Galena

Galena is the most abundant ore mineral present, comprising greater than 30 % of the valuble minerals in the ore. For the most part the galena is well crystallized, and in polished sections numerous triangular cleavage pits, and cubic cleavage traces are present. The mineral occurs in nearly all of the sections studied, and where it composes the bulk of a section it forms a mass surrounding the sulpho salts and a few grains of unreplaced sulphides. Economically this is the most important mineral in the ore, for it is in galena that the gold and silver bearing minerals occur.

Evidence present strongly suggests that the deposition of the galena was later than that of sphalerite. Replacement of sphalerite by galena is evidenced by numerous embayments (caries texture), tongues and projections of galena extending into sphalerite. However, only a few veinlets of galena cutting sphalerite were observed. The replacement appears to have been "en mass". In specimens composed predominately of sphalerite, the galena occurs in poorly crystallized patches surrounded by sphalerite. The nature of the grain boundaries seems to suggest replacement of sphalerite by galena, and that the grains represent the initial stages in the replacement of the sphalerite.

Gold

Gold is relatively abundant in one section (section # 9). The section is composed almost entirely of well crystallized galena with a gangue of quartz. The gold occurs as small round, sub-rounded, and lath-like grains sitting in a groundmass of galena. The distribution of the grains is random, and the gold does not appear to be closely associated with any of the other minerals occuring in the galena, that is the grains are completely surrounded by galena. The grain size of the gold ranges from a maximum of 50 X 20 microns, to a minimum of 3 X 2 microns; particles smaller than the minimum may have been overlooked. The majority of the grains tend to be round or sub-rounded and the average diameter of the grains is from 15 to 20 microns. The color of the gold is pale yellow, possibily indicating a relatively high silver c ontent. Etched with KCN the grains turn black in a full minute. Deposition of the gold appears to be contemporaneous with that of galena.

Problems involved in extracting the gold do not appear serious. The gold is of sufficient size, and its occurence in galena would make extraction from a lead concentrate relatively easy.

Tetrahedrite

Tetrahedrite forms less than 2 % of the ore minerals present. It is closely associated with galena and was not noted to occur in any other mineral. The tetrahedrite occurs as irregularly shaped bodies sitting in a groundmass of galena. The grains vary greatly in size, from 50 to several hundred microns in length. Smaller grains are more numerous than larger ones. Most of the tetrahedrite bodies are randomly scattered throughout the galena, but some have a tendency to occur along the boundaries of other minerals (e.g. pyrrhotite and quartz) occuring in the galena. Plate V illustrates both large and small grains of tetrahedrite occuring in galena. A microchemical test for silver was negative.

Deposition of the tetrahedrite appears to have been simultaneous with galena. No definite criteria indicating which of the two minerals deposited first was observed. The close association of the two minerals and the nature of the grain boundaries is indicative of contemporaneous deposition. Some of the tetrahedrite may be due to exsolution from galena.

Pyrargyrite

Pyrargyrite is the most abundant silver bearing mineral in the ore. It is most abundant in the coarse grained galena specimens and section # 3 contains upto 30 % of the mineral. Diagnostic etch tests, brilliant red internal reflection and a positive microchemical test for antimony identified the mineral. Pyrargyrite occurs in various forms, intimately associated with galena. It occurs as veinlets ranging from 10 microns to 2 or 3 millimeters in width, and as irregular grains having a similar range in size. The pyrargyrite replaces galena along the latter's cleavage planes, and in places replaces large areas of galena, (see Plate VI). Cubic cleavage of the galena is well preserved by the pyrargyrite. For some reason or another replacement is not extensive laterly from the cleavage planes. It appears as if the pyrargyrite solutions used the cleavage planes as an avenue of access, and chose for one reason or another, certain places to replace larger areas of galena. This selection may be governed in part by the intersection of

follows line of least resistance.

cleavage planes, of different crystals, at acute angles or nearly at right angles thus producing a "daming" effect which would allow more time for the mobile pyrargyrite solutions to replace larger areas of galena. It was also noted that many of the pyrargyrite grains occur in embayments extending into other minerals (e.g. arsenopyrite, sphalerite and pyrrhotite, see Plate I). It is probable that these corroded embayments were intially produced by galena, and later pyrargyrite solutions traveling along cleavage planes in galena became damed by the other mineral. The pyrargyrite selectively replacing the galena, rather than the "daming" mineral.

Numerous narrow veinlets of pyrargyrite cutting tetrahedrite were also observed (Plate V).

Stephanite (?)

The tentative identification of this mineral is based its observed properties and etch tests, which are listed below.

Color:- grey, with a bluish tinge
Polish:- smooth
Hardness:- B
Anisotropism:- strong, pinkish-grey to grey
Internal reflection:- none
No apparent cleavage or twinning
Etch tests
  $HgCl_2$ - stains brown to irid quickly
  KOH - stains grey after full minute
  KCN - stains black quickly
  $FeCl_3$, HCl, and HNO_3 - negative

Only one grain of the mineral could be recognized and this occurs in section # 3. The grain is roughly rectangular in shape and measures 160 X 50 microns in size. It occurs isolated in a mass of tetrahedrite, which in turn is closely associated with pyrargyrite and galena.

Stannite (?)

This mineral occurs in section # 9, and its tentative identification is based on the following properties.

Color:- greenish-grey
Polish:- smooth, with a few pits
Hardness:- D
Anisotropism:- weak, but distinct, greenish-grey to grey
Habit:- prismatic
No internal reflection
No apparent cleavage or twinning
Etch tests
  $HgCl_2$, KOH, KCN, $FeCl_3$, and HCl negative
  HNO_3- differential etch, irid.

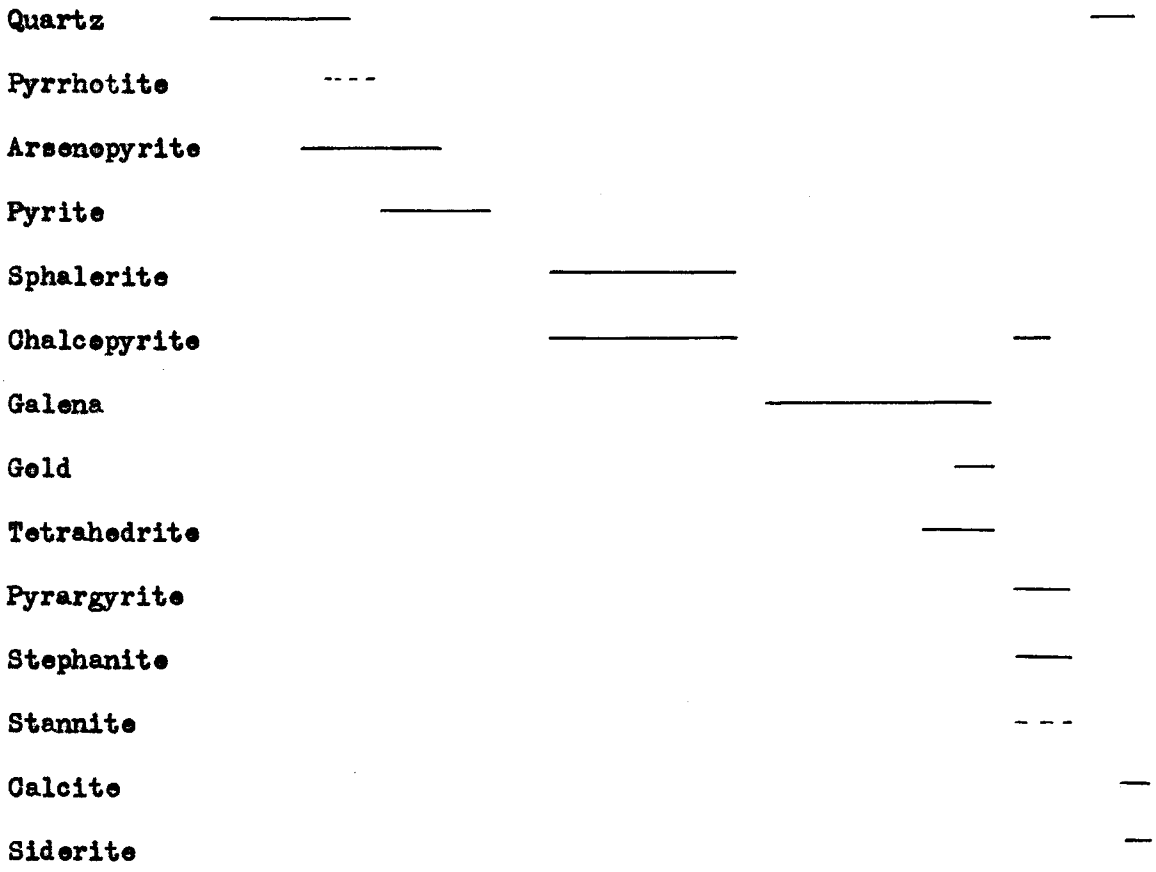
Plate VI illustrates the occurence of this mineral, and this was the only grain observed. The mineral is closely associated with sphalerite, galena and pyrrhotite.

Paragenesis

In the preceeding descriptions of individual minerals, evidence regarding paragenesis is cited wherever possible. There appears to have been two periods mineral deposition in the ore. The first period represents deposition from solutions of relatively high temperatures. Quartz, arsenopyrite, pyrrhotite and pyrite were the minerals deposited in this initial stage of mineralization. Fault movements fractured the dyke rocks and produced avenues along which the mineral bearing solutions could permeate. Quartz, arsenopyrite and possibly pyrrhotite were the first minerals to deposit. The quartz replaced and silicified fragments of dyke rock, and where space was available developed euhedral crystals. Deposition of arsenopyrite, pyrrhotite and pyrite in part was simutaneous with quartz, but there appears to be some overlapping, with pyrite being the last mineral to deposit.

Following the first period of mineral deposition further fault movements re-opened old channels and fractured many of the pyrite grains. The mineral bearing solutions of this second period of mineralization deposited the bulk of the base metal sulphides present in the ore. These solutions were probably of lower temperature than the initial solutions. The first mineral to deposit during this second period of mineralization was pyrite, and following ashort time gap sphalerite and chalcopyrite deposited. The sphalerite and chalcopyrite deposited simultaneously. Closely following the deposition of sphalerite and chalcopyrite, large quantities of galena were deposited. Tetrahedrite and gold deposited at the same time as the galena. A short time lag appears to have occured after the deposition the galena. Following this time lag pyrargyrite and small amounts of chalcopyrite were deposited. A late period of fault movement opened small fratures and these fractures were filled with quartz, calcite and siderite. The paragenetic sequence is diagrammatically illustrated on the next page.

PARAGENETIC SEQUENCE

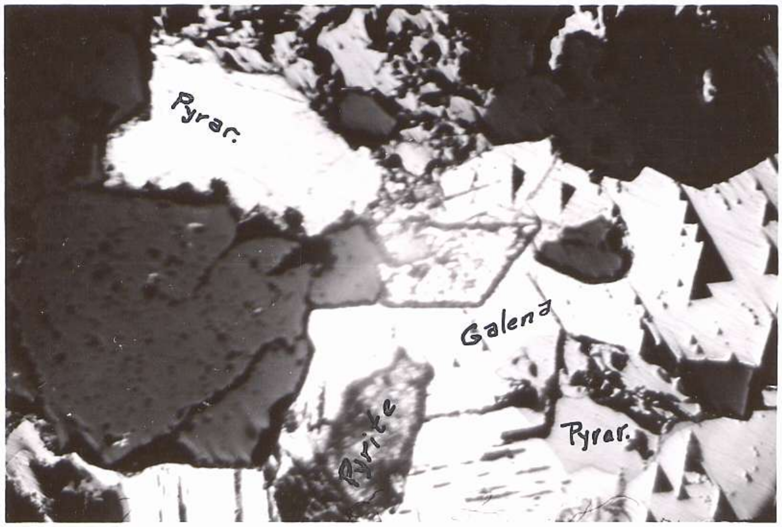


Type of Deposit

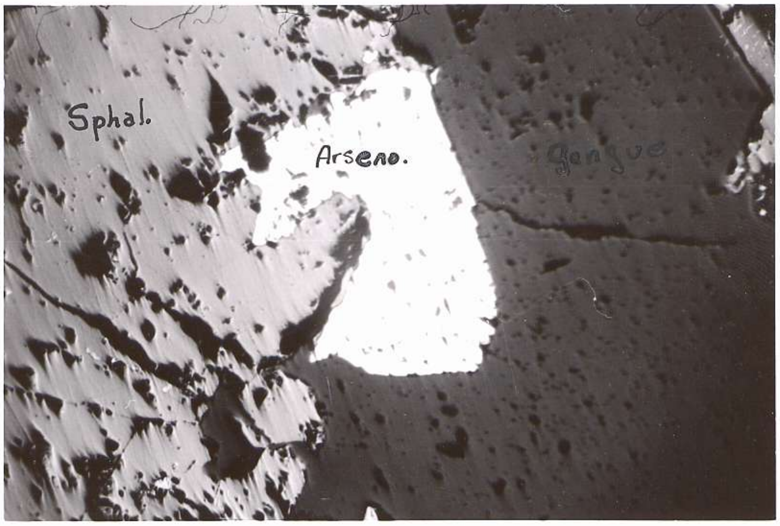
The mineral assemblage of the ore indicates a relatively wide range in temperature. However, the bulk of the minerals present are typically moderate temperature types. The presence of pyrrhotite, which is a high temperature mineral, need not seriously be considered in a temperature classification of the ore due to its rare occurence in the ore. Exsolution of chalcopyrite from sphalerite would indicate a temperature of about 350 to 400°C.

The vuggy nature of some of the specimens and the presence~~s~~ of a quartz-calcite-siderite gangue indicates the deposit is one of moderate temperature. An abundance of hypothermal minerals, both ore and gangue is lacking, and similarly good epithermal criteria is lacking. Therefore on the basis of the mineral assemblage and the textures of the ore, the deposit is best classified as a mesothermal deposit.

PLATE - 1

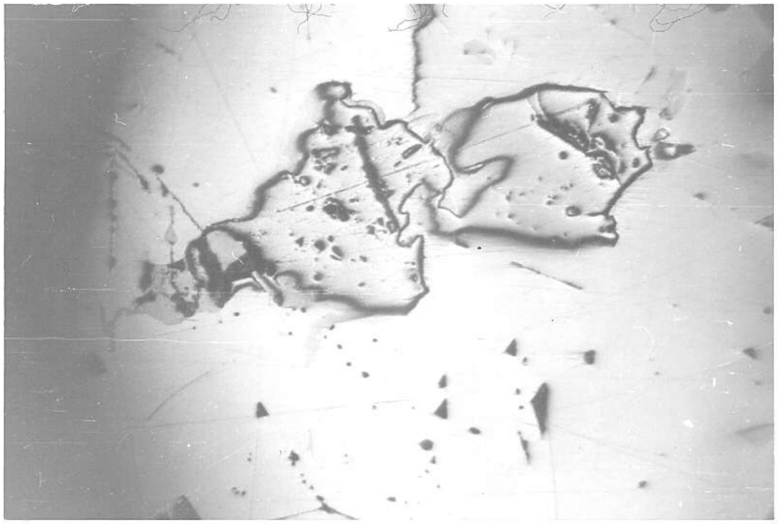


X150
Rhombic grain of arsenopyrite being replaced by pyrargyrite.



X150
Sphalerite replacing arsenopyrite.

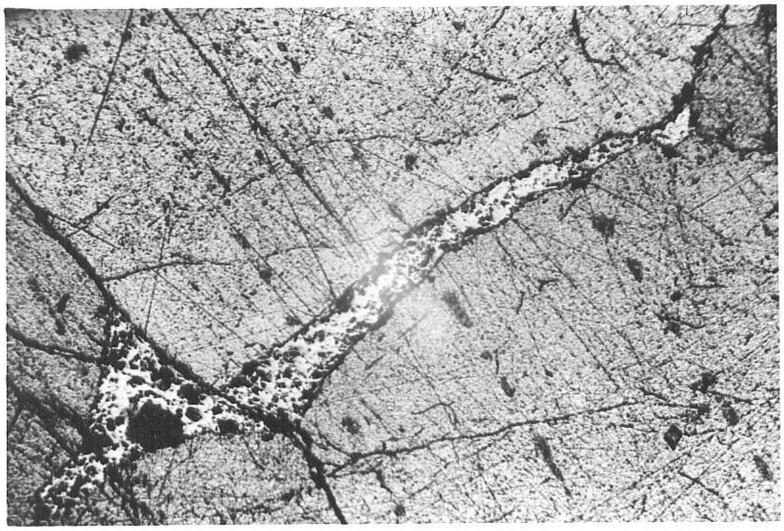
PLATE - II



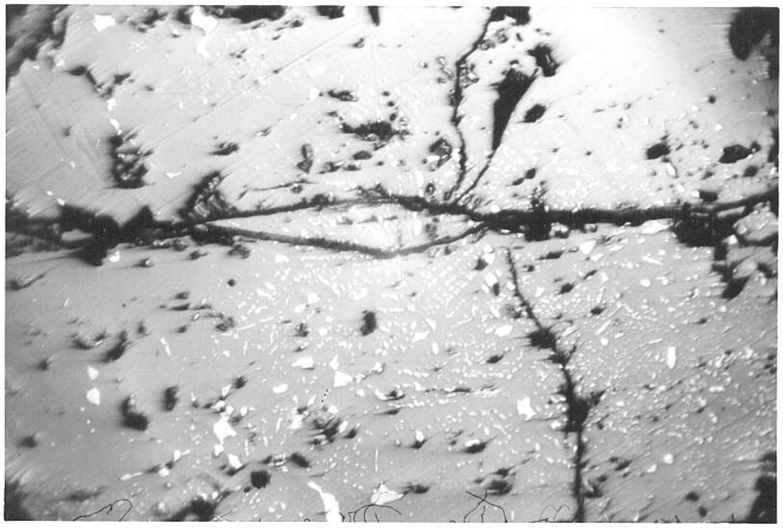
X150
Corroded pyrrhotite grain sitting in galena.

X150
Fractured pyrite grain. Fractures filled with quartz.

PLATE - III

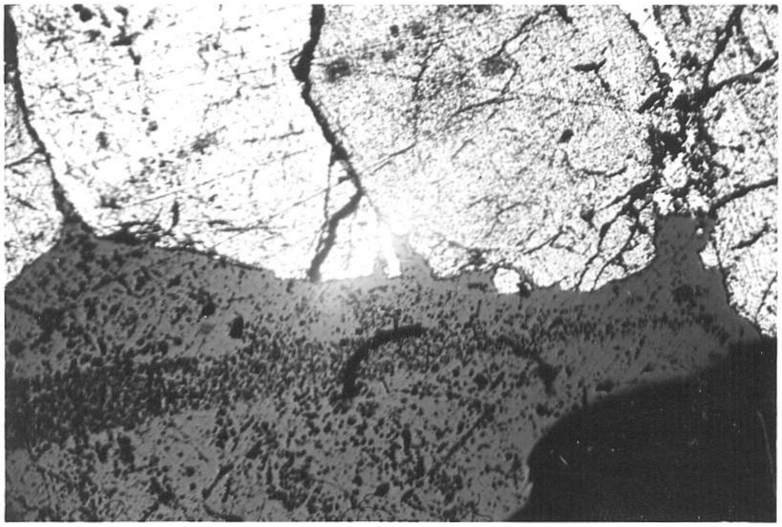


X150
Chalcopyrite veinlet in pyrite.

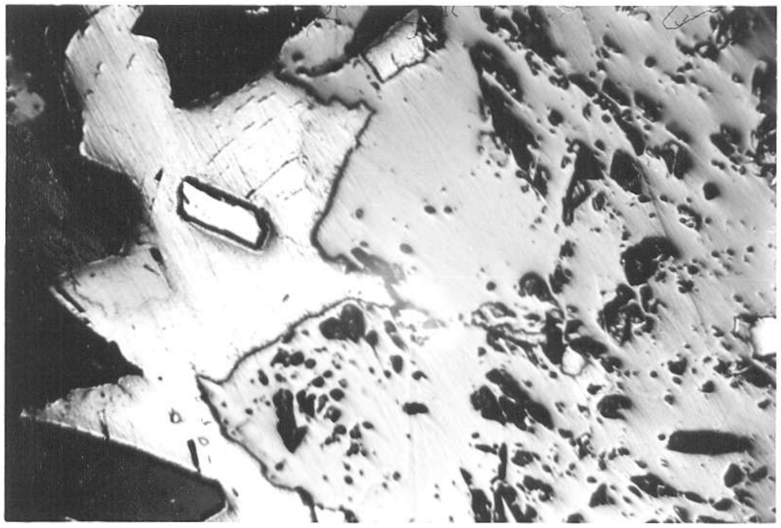


X150
Emulsion texture of chalcopyrite (light) exsolution bodies in sphalerite (dark).

PLATE - IV

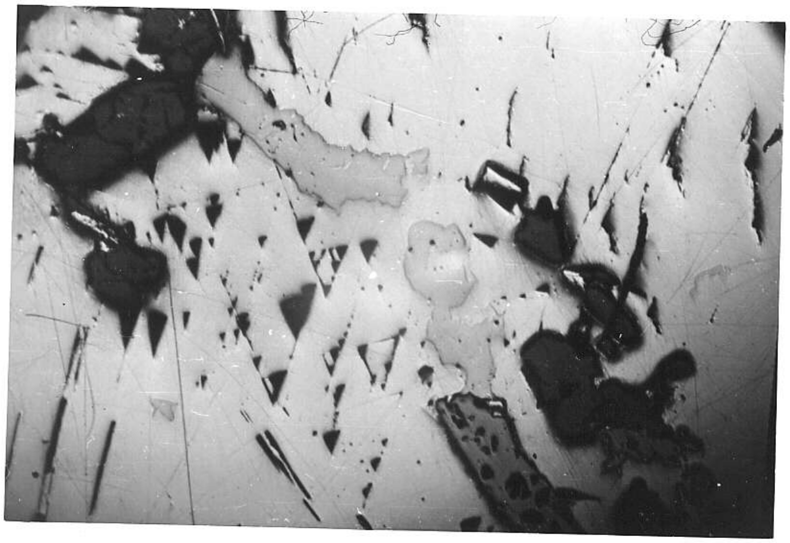


X80
Projections of sphalerite extending into fractured pyrite.



X150
Galena (light) replacing sphalerite (dark). The light lath-like grain is arsenopyrite.

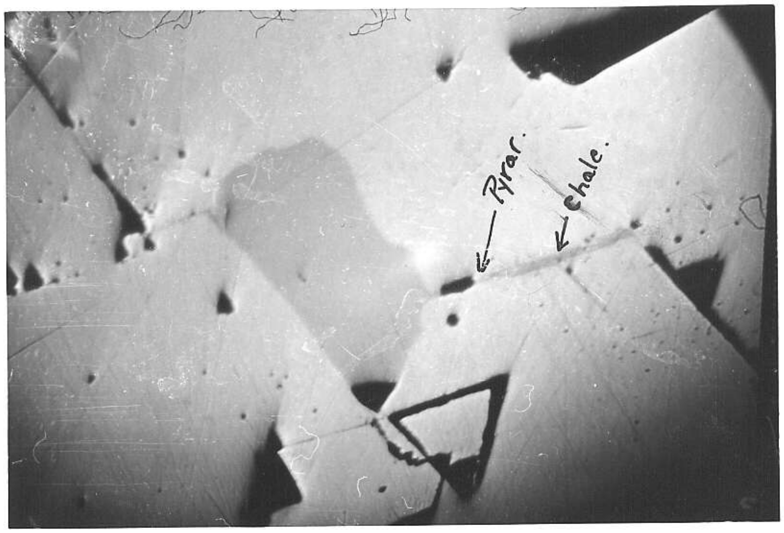
PLATE - V



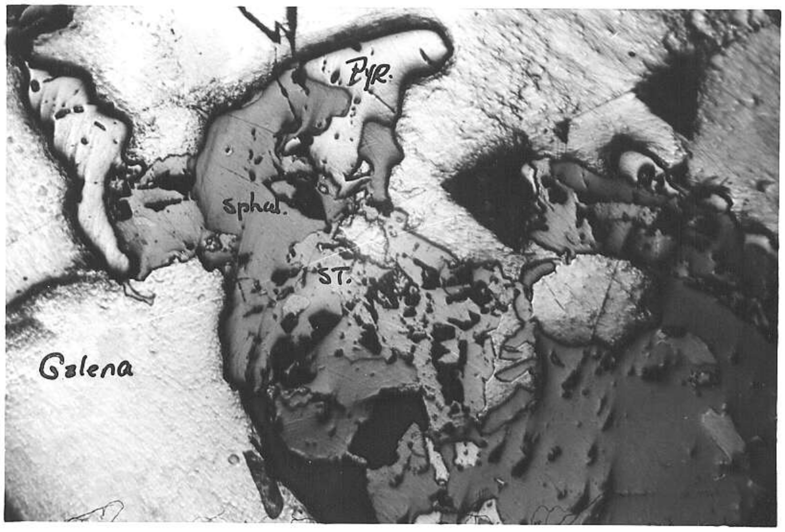
X150
Irregular bodies of tetrahedrite (grey) in galena (light). The dark grains are quartz.

X150
Stringers of pyrargyrite cutting tetrahedrite.

PLATE - VI



X150
Large grain of pyrargyrite in galena. Note the pyrargyrite and chalcopyrite in cleavage planes of galena, and the preservation of cleavage by the pyrargyrite.



X150
Stannite associated with sphalerite, pyrrhotite, and galena.

BIBLIOGRAPHY

Annual Reports, Minister of Mines, B.C. : 1921-34

Cockfield, W.E. Silver-lead Deposits in Atlin District, B.C., Geol. Surv. Canada, Sum. Rept., Part A , 1925.

Donaldson, T.J. A Mineralographic Report of Atlin Ruffner Ores, University of B.C. , Geology 409, 1953.

Edwards, A.B. Textures of the Ore Minerals., Aust. Inst. Min. Met, 1947

Lindgren, W. Mineral Deposits, McGraw-Hill, 1933

Okulitch, V.J. Ore Deposits of the Eastern Side of the Coast Range Batholith (with special reference to the Atlin District), University of B.C. , M.A.Sc. thesis, 1932.

Short, M.N. Microscopic Determination of Ore Minerals, U.S.G.S., Bull 914, 1948.

Uytenbogaardt, W. Tables for Microscopic Identification of Ore Minerals, Princeton Univ. Press. , 1951