

600119

SALLY MINES

Beaverdell, B. C.

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Geology 9

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INTRODUCTION

This report is based on laboratory work done in Geology 9 at the University of British Columbia. Polished sections were prepared from a suite of ore of the Sally Mines, Beaverdell, B. C., and studied under the microscope to identify minerals present, and work out their sequence of deposition. It was also hoped to establish whether secondary processes have played any part in the enrichment of the ore.

The writer wishes to acknowledge the assistance of Dr. H. V. Warren under whose supervision the work was carried out. Thanks are also due J. Donnan who assisted in preparing sections and J. De Leen who lent aid in general laboratory technique.

A MICROSCOPIC STUDY
OF THE ORES OF
THE SALLY MINES, BEAVERDELL, B. C.

General

The Sally Mines are located in the Beaverdell map area, B. C., several miles East of Beaverdell on the Western slope of Wallace Mountain. Easy access to the area is had by the Kettle Valley Railroad along the West side of the Westkettle River. A road runs from the town of Beaverdell to the Sally Mines.

General Geology

The oldest rocks in the area are the Wallace group, an assemblage of volcanics with minor clastic and chemical sediments, schists and intrusives. They have been intruded and metamorphosed first by the Westkettle batholith and later by the Beaverdell batholith. These rocks are overlain unconformably by the Curry Creek Series of conglomerates and tuffs. The youngest rocks in the area are the Nipple Mountain Series of lavas which overly all older rocks unconformably.

The host-rock of the Sally Mine is the Westkettle batholith, a medium-grained quartz diorite. The deposit is probably genetically related to the Beaverdell quartz monzonite.

Geology of the Ore Deposit

The Sally Mine is essentially a mineralized shear zone in the Westkettle batholith. The batholith is an even-grained quartz diorite containing feldspar, quartz, biotite and hornblende as main constituents. The main rock mass is medium-grained with a fine-grained marginal facies at the contact with the Wallace Group. The rock on the whole is fresh and unaltered, but along major shear zones has been intensely altered to a greenish amorphous mass of clay minerals, chlorite and sericite.

Mineralogy

The ore is principally pyrite, galena, sphalerite and pyrargyrite in a quartz gangue. Minor amounts of other minerals occur, including chalcopyrite, arsenopyrite, polybasite, tetrahedrite, acanthite and native silver. Deposition of sulfides was preceded by intense sericitization along the shear zone.

Genesis

The source of the mineralizing solutions was probably the Beaverdell batholith. End-phase gases and hydrothermal solutions emanating from the batholith found their way into cracks and fissures in the overlying Westkettle batholith and deposited their load partly by filling cavities in the brecciated shear zones and partly by replacing the country rock. Channels for these solutions were probably developed by stresses set up during the emplacement of the Beaverdell batholith.

Control of Deposition

The main element of control seems to have been the relatively high competence of the Westkettle quartz diorite compared to the overlying Wallace group. Fractures and shears tended to develop

readily in the competent Westkettle batholith and died out upon passing into the Wallace Group. The overlying Wallace Group dammed ascending ore solutions and concentrated them along the shear zones in the Beaverdell batholith.

Secondary Processes

The zone of oxidation rarely extends more than a few feet below the present surface, although major fissures and shears may show effects of surface waters to a considerable depth.

Calcite, clay minerals and native silver occur in cross faults which frequently displace the orebodies. The clay minerals are residual products from the chemical decomposition of feldspar. Calcite and native silver may have been precipitated from descending surface waters. More will be said later regarding the origin of native silver in the ore.

Megascope Examination of the Ore

A brief study was made of hand specimens to obtain general features of the ore not apparent in polished sections.

The most abundant metallic minerals are pyrite, galena, sphalerite, and pyrargyrite, but polybasite, acanthite, native silver, chalcopyrite, and bornite stain were noted in hand specimens.

The main gangue mineral is quartz with some calcite, clay minerals, and chlorite.

Locally, the ore is well banded, in some places with regularity from centre to each margin, but is typically an aggregate of coarse, inter-locking crystals of sulfides and gangue.

The wall-rock and included fragments of country rock are highly altered but the contact between vein material and wall-rock is sharply defined. The zone of alteration is narrow and is apparently due only to the effect of the ore-bearing solutions.

Pyrite, sphalerite and quartz are highly fractured and ^{corroded} heated by later sulfides. All minerals present are veined by calcite stringers filling fractures which run from parallel with, to perpendicular to the direction of banding, but typically cutting the banding at a large angle, suggesting movement parallel with the fractures subsequent to the main period of ore deposition.

Local drusy cavities and partially filled vugs are common. They usually contain bladed crystals of calcite or slender crystals of quartz, the latter commonly growing on pyrite. One vug was noted partially filled by two intergrown crystals of polybasite exhibiting perfect crystal form. A finely crystalline crust of quartz had grown on the polybasite, indicating a late period of quartz deposition.

Pyrite, sphalerite, and galena are usually intimately associated as interlocking granular masses or in alternate narrow bands.

Pyrite also occurs as coarse, granular aggregates and finely disseminated grains or euhedral cubes in quartz.

Sphalerite is abundant as coarsely-crystalline, cleavable masses or fine crystalline aggregates. It varies from amber-brown to black in color, indicating a variable iron content. Often the brownish variety can be seen to grade imperceptibly into the dense black variety known as marmatite.

Cube galena is common in large masses, well crystallized and highly cleavable. In one specimen "steel" galena was noted in narrow

bands alternating with bands of crystalline galena exhibiting a prominent gneissic structure approximately parallel to the banding. This indicates movement along the vein sometime after deposition of the galena.

Pryargyrite is fairly abundant, usually as fine-grained bands and pockets closely associated with galena. The mineral is common where banding is prominent and is invariably mixed with, or in contact with, galena.

Acanthite occurs in specimen number 11 as flat scales up to $\frac{1}{4}$ ins. on quartz. The mineral appears closely related to fracture planes in the quartz, suggesting secondary origin, or at least very late deposition. Acanthite is commonly intergrown with chalcopyrite which locally shows bornite stain. The acanthite exhibits a prominent arborescent structure, with locally ~~almost~~ a very fine needle form. It is very soft and sectile, has a bluish-black color and metallic lustre.

Native silver is fairly common as flat, hackley scales upon fracture surfaces sometimes characterized by polishing and slickensides. The silver is highly tarnished, often with a dense, black, sooty surface. Native silver observed in hand specimens has every indication of secondary origin but judgment was reserved until the mineral was studied in section.

Iron staining is rare but locally appears in vugs and as surface coating on ~~pyrite~~^ppyrite and sphalerite.

Microscopic Description of Minerals

Polished sections were studied under the microscope. Lack of time did not permit as complete a study as was desirable and the writer feels much yet remains to be learned about the deposit.

The following minerals were identified in section:

Quartz	Galena	Acanthite
Pyrite	Pyrargyrite	Native Silver
Arsenopyrite	Polybasite	Chalcopyrite
Sphalerite	Tetrahedrite	Calcite

Pyrite

Pyrite is the most abundant metallic mineral and occurs as highly shattered, irregular masses and residuals in nearly all other minerals present. It is corroded and veined by quartz, calcite, sphalerite, galena, and the silver sulfides. Euhedral crystals are rare but some do appear in quartz.

Sphalerite

Sphalerite is also abundant in irregular masses, usually crackled and healed by quartz, galena, pyrargyrite, polybasite, and tetrahedrite. Long, narrow veinlets of polybasite, galena, and pyrargyrite often cut the sphalerite, one veinlet sometimes containing a succession of the three minerals. Where several of such veinlets appear close together they are usually parallel, suggesting control by crystallographic directions in the sphalerite.

Most of the sphalerite present is characterized by countless, small, rounded, or elongate inclusions of chalcopyrite, often evenly distributed and definitely oriented in two systems with their long directions approximately at right angles. The chalcopyrite was undoubtedly exsolved from the sphalerite as the latter cooled.

Other sphalerite occurs which is noticeably deficient in chalcopyrite and it was hoped on this basis to establish two periods

of zinc mineralization or at least a relation between amount of exsolved chalcopyrite and depth in the orebody. This latter type of sphalerite commonly occurs as a narrow, very irregular border between galena and pyrargyrite and it was thought may have been controlled by the contact between these two minerals. The pyrargyrite side of the sphalerite is commonly much more irregular than the contact of sphalerite with galena. Close to the contact many "islands" of sphalerite occur in the pyrargyrite with few or none in the galena. This indicated clearly, if the sphalerite be assumed later than the galena and pyrargyrite, it showed a greater tendency to replace pyrargyrite than galena. Much work, however, failed to substantiate the theory of a late generation of sphalerite, and the writer now believes the sphalerite border is probably nothing more than a residual rim left after most of a larger mass of sphalerite has been replaced by pyrargyrite. Why this residual border would be so common between galena and pyrargyrite is not yet understood by the writer.

Having assumed a single age of sphalerite, the writer felt some relation might exist between depth and chalcopyrite content in sphalerite but correlation of sections with depth of parent specimens in mine failed to establish anything like consistent results.

Arsenopyrite

Arsenopyrite is rare, but is locally abundant as small euhedral to anhedral crystals in most other minerals present. It commonly exhibits the characteristic diamond-shaped crystal outline. It is corroded by most minerals present, yet exists in these same minerals as perfect euhedral crystals. Its true relationship is not completely understood but it is believed to be early with possibly some later

metacrysts. It is common at grain boundaries, perpendicular to contacts and projecting into each of the minerals in contact. Its dispersal throughout most of minerals is probably due to early crystals being engulfed and surrounded by later mineralizing solutions.

Pyrargyrite

Pyrargyrite is fairly abundant and is commonly intimately associated with galena and tetrahedrite. In one section it appeared to vein galena but this relation could not be seen elsewhere. It is very commonly intergrown with smooth rods of polybasite, indicating simultaneous deposition of the two minerals. It contains many small blebs of sphalerite and euhedral to anhedral crystals of arsenopyrite.

Tetrahedrite

Tetrahedrite is not abundant but occurred extensively in section B. It has smooth contacts with galena and pyrargyrite, in some places intergrown with the latter. It appears to vein sphalerite.

Polybasite

Polybasite is fairly abundant, usually intimately associated with pyrargyrite. It occurs as smooth veinlets in sphalerite and is common as a small tip on the end of a projection of pyrargyrite. It is also often associated with acanthite, and in some cases, galena.

^{Polybasite}
~~This mineral~~ was difficult to identify, especially when associated with pyrargyrite.

It was identified from pyrargyrite by:

- (1) Slight greenish-grey color.
- (2) High anisotropism from green to violet to grey.

It was identified from tetrahedrite by:

- (1) Lower relief.
- (2) Smoother polish.
- (3) Greenish tinge.
- (4) Anisotropism.

After a little practice the writer found the above criteria quite satisfactory to identify polybasite without resorting to etch reactions.

Galena

Galena is very abundant as irregular masses in pyrite, quartz and sphalerite. Much difficulty was encountered in obtaining a smooth polish on the galena, and in most sections it was characterized by many minute triangular pits. Galena is veined by smooth veins of pyrargyrite whose orientation seems controlled by crystallographic directions in the galena.

Galena occurs in smooth contact with pyrargyrite, tetrahedrite, polybasite and acanthite.

Chalcopyrite

Chalcopyrite is a very minor sulfide, its main occurrence already mentioned, as exsolved particles in sphalerite. It also veins sphalerite and occurs as small ^{blebs} ~~beils~~ in quartz and galena.

Its most interesting habit is as a narrow rim or outgrowth on acanthite. Invariably the ^{chalcopyrite and acanthite} ~~two minerals~~ are associated but rarely intergrown or admixed. Several times chalcopyrite was seen completely rimming a grain of acanthite, with fairly smooth contacts between the two minerals, but with an occasional apophyse of chalcopyrite extending

into the acanthite.

Native Silver

Native silver is rare but was observed in several sections associated with polybasite and acanthite. It commonly occurs with these ~~other~~ minerals in quartz but was noted in chalcocite gangue and in fractures in pyrite. It occurs in smooth contact with acanthite and polybasite, as tiny rounded blebs in acanthite, at contacts between acanthite and polybasite or as border around acanthite. Many occurrences suggested a small pocket of Ag - S ^{solution} liquid in quartz with an excess of silver which was precipitated in small blebs or as a border phase after sulphur had been used up.

The writer is not satisfied that all native silver in the ore is primary. However, that observed in section appears to be definitely of hypogene origin.

Acanthite

This mineral was discovered late and little time was left for a careful study. While it was not positively identified, the writer feels fairly certain the mineral found is acanthite. It occurs principally as small patches in quartz associated with chalcopyrite, native silver, polybasite and galena. It is in smooth contact with all these minerals.

It is characterized by:

- (1) Slight anisotropism.
- (2) Dirty grey color intermediate between polybasite and sphalerite.
- (3) Multitude of fine scratches extending entirely across the mineral.

- (4) Common association with chalcopyrite and native silver.

The mineral was etched with all reagents, but work was handicapped by insufficient surface area to work on and rare occurrence in the sections. Each test was made three times, often on the same surface as the previous reaction. The writer was unable to compare results with any authoritative ~~results~~^{work} but lists the following results, which, while not to be relied on, may prove helpful to later workers.

Where conflicting results were obtained all are given:

- KOH - negative
- HgCl₂ - iridescent - rubs off with difficulty and leaves slight brown stain.
- KCN - stain blackish-brown very quickly - rubs off easily if not allowed to go too far.
- FeCl₃ - (1) Very slight grey stain - darkest at edge of drop
(2) Irredescence slowly - hard to rub off
- HNO₃ - Light brown differential stain - partially rubs off
- H Cl - (1) Brown- will not rub off
(2) Light brown - rubs off
(3) Black differential etch - left on a long time

Quartz

Quartz is the principle gangue mineral present. It is highly fractured and healed by sulfides and in some cases later quartz. It also occurs as euhedral to subhedral crystals in sphalerite, galena and pyrargyrite. Euhedral crystals were also noted cutting veinlets of calcite which transected all other minerals in the section. Because it is improbable that the other minerals, principally sphalerite, would fracture while the quartz would not, this may represent a very late period of quartz deposition.

Calcite

Calcite is a very minor gangue mineral, occurring principally in irregular veinlets which cut all other minerals present.

Summary

Before discussing the paragenesis of the minerals, the following important facts should be borne in mind from what has gone before:

- (1) Quartz, Pyrite and sphalerite intensely shattered.
- (2) Chalcopyrite unmixed from sphalerite.
- (3) Intimate association and smooth contacts between pyrargyrite, polybasite, galena and tetrahedrite.
- (4) Close association between polybasite, acanthite, native silver, galena, and chalcopyrite.
- (5) Quartz veined by and veining sphalerite, and transecting calcite stringers.
- (6) Calcite-filled fissures cutting all sulfides present.

Paragenesis

Results obtained suggested subdivision of ore deposition into four periods as follows:

- (1) Medium temperature phase - deposition of quartz, pyrite, chalcopyrite, sphalerite, and arsenopyrite.

Major Fracturing

- (2) Main period of deposition - more quartz, galena, pyrargyrite, tetrahedrite, polybasite, chalcopyrite and probably more sphalerite and arsenopyrite
- (3) Low temperature, rich phase - deposition of polybasite, acanthite, chalcopyrite, native silver and galena.

Faulting and Fracturing

(4) Secondary Processes - calcite and native silver (?)

The second and third periods of deposition should probably be included as one major, extended period, rather than be subdivided; but there is definitely indicated a drop in temperature conditions and a resulting change in mineral associations. The time that must be ascribed to such a period is not definitely known but it is probably sufficiently long that loss of heat by cooling and conduction would account for lower temperature conditions prevailing.

Quartz was the first mineral deposited, probably before and simultaneously with, pyrite and arsenopyrite. Arsenopyrite, in part at least, could have been deposited almost any time from relations seen in section. Sphalerite, and chalcopyrite came next, apparently mainly filling cavities and showing little tendency to replace quartz or pyrite. Sphalerite was observed corroding and replacing arsenopyrite. Chalcopyrite was not deposited at this period as a separate mineral, but only as exsolved blebs in the sphalerite.

Then came a major period of deformation in which pyrite, quartz, and sphalerite were intensely shattered.

More quartz was deposited, typically filling fractures in sphalerite. Galena, tetrahedrite, pyrargyrite and polybasite were deposited simultaneously, in part at least. They all vein sphalerite and quartz. There is some evidence of pyrargyrite veining galena and polybasite veining pyrargyrite.

Then acanthite, chalcopyrite and native silver were deposited contemporaneously.

The following would summarize results obtained on the relations of these minerals:

- (1) Galena, pyrargyrite and tetrahedrite starting early after period of fracturing.
- (2) Tetrahedrite stops being deposited in relatively short time.
- (3) Galena and pyrargyrite go on simultaneously and are joined by polybasite.
- (4) Pyrargyrite stops, ^{poly}polybasite and galena continue and are joined by acanthite, native silver and chalcopyrite.

The evidence in favour of chalcopyrite being restricted to the low temperature phase is not very strong and it is possible its true relation is not understood.

The deposition of metallic minerals was succeeded by faulting and fracturing, and calcite and possibly native silver were deposited. More will be said concerning native silver later.

Classification of Deposit

The Sally ore appears to be a typical example of the type of mineral deposit known as mesothermal, or medium temperature. Minor amounts of native silver and acanthite indicate a low-temperature end-phase. It is essentially a cavity filling with minor replacement and dominantly of hypogene origin.

Conclusions

- (1) Silver in the ore is derived mainly from pyrargyrite and polybasite with minor amounts in acanthite and native silver. While no assays were made, it is quite probable that galena and tetrahedrite present are also argentiferous.

(2) Pyrargyrite, polybasite and acanthite present, are undoubtedly primary or hypogene constituents of the ore. They are fresh, intimately associated with unaltered, primary ~~constituents of the ore~~ ^{minerals} and present no characteristics common to supergene minerals.

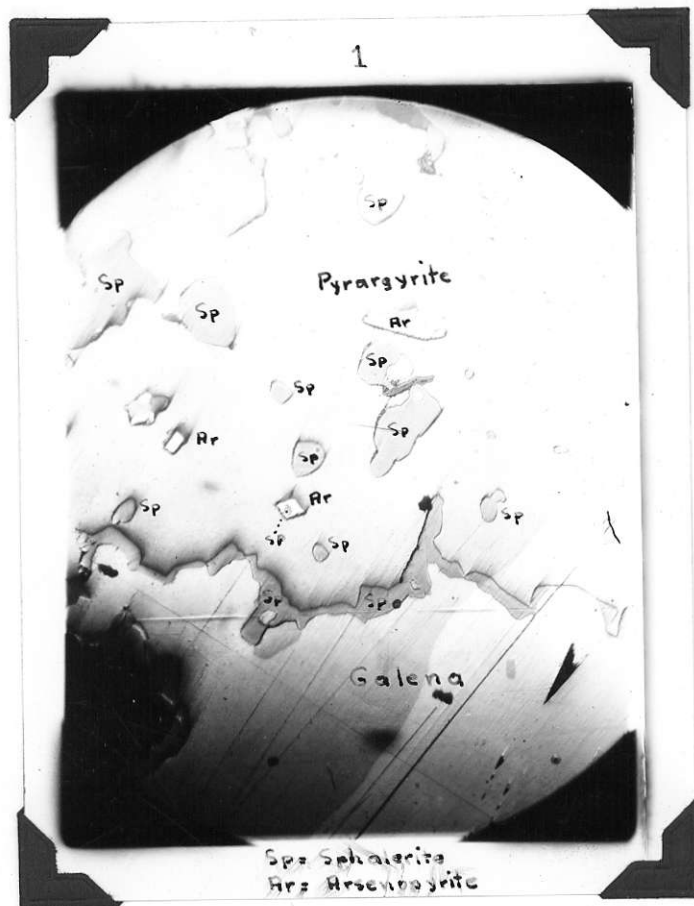
Some of the native silver present, however, may be of secondary origin. That observed in section appeared primary but the hackley, sooty scales seen in hand specimens on slickensided fault surfaces could easily have been deposited by descending surface waters. It is commonly accepted that acanthite is easily decomposed to produce native silver, so in a deposit such as this, where this mineral is present, it should be logical to assume that some silver has been deposited by surface agencies. However, undoubtedly, the greater part of the silver in the Sally ore is of hypogene origin.

(3) As the ore from the mine has already been treated to extract silver, it was felt unnecessary to dwell on the metallurgical aspects of the ore.

It might be worth noting that if a zinc concentrate were desired it would be high in copper as it would be impossible to eliminate many of the small exsolved blebs of chalcopyrite in the sphalerite. Lead and the silver sulphides would be easily separated but crushing would have to be very fine to free many of the particles of native silver present.

SEQUENCE OF SEPARATION

Fe	<hr/> Pyrite	<hr style="border-top: 1px dashed black;"/> Arsenopyrite			<hr style="border-top: 1px dashed black;"/> -----?
As		<hr style="border-top: 1px dashed black;"/> Arsenopyrite	??		
Zn		<hr style="border-top: 1px dashed black;"/> Sphalerite		<hr style="border-top: 1px dashed black;"/> Sphalerite?	
Cu		<hr style="border-top: 1px dashed black;"/> Chalcopyrite	<hr style="border-top: 1px dashed black;"/> Tetrahedrite		<hr style="border-top: 1px dashed black;"/> chalcop.?
Pb			<hr style="border-top: 1px dashed black;"/> Galena		
Sb			<hr style="border-top: 1px dashed black;"/> Pyrargyrite Polybasite	<hr style="border-top: 1px dashed black;"/> Tetrahedrite	<hr style="border-top: 1px dashed black;"/> Polybasite
Hg			<hr style="border-top: 1px dashed black;"/> Pyrargyrite	<hr style="border-top: 1px dashed black;"/> Polybasite	<hr style="border-top: 1px dashed black;"/> Acanthite Native Hg.
S		<hr style="border-top: 1px dashed black;"/> Pyrite			<hr style="border-top: 1px dashed black;"/> Acanthite
CO ₂					<hr style="border-top: 1px dashed black;"/>
SiO ₂	<hr style="border-top: 1px dashed black;"/> Quartz	<hr style="border-top: 1px dashed black;"/>	<hr style="border-top: 1px dashed black;"/> Quartz		<hr style="border-top: 1px dashed black;"/> ? Qtz



Section G

PLATE #1

Microphotograph showing typical sphalerite border at galena-pyrrargyrite contacts. This is a common occurrence in many of the sections. The contact with pyrrargyrite is usually much more irregular than is shown in the picture. Note the numerous blebs of sphalerite in the pyrrargyrite and the lack of sphalerite in the galena. Euhedral and subhedral crystals of arsenopyrite appear in the pyrrargyrite. The lower central diamond-shaped crystal contains a central core of sphalerite, possibly indicating incipient replacement of arsenopyrite by sphalerite.



PLATE #2
Section 3-B

Acanthite, polybasite, silver and chalcopyrite in quartz. The rim of chalcopyrite extends completely around the acanthite. Two round blebs of native silver appear at the edge, in smooth contact with the chalcopyrite.

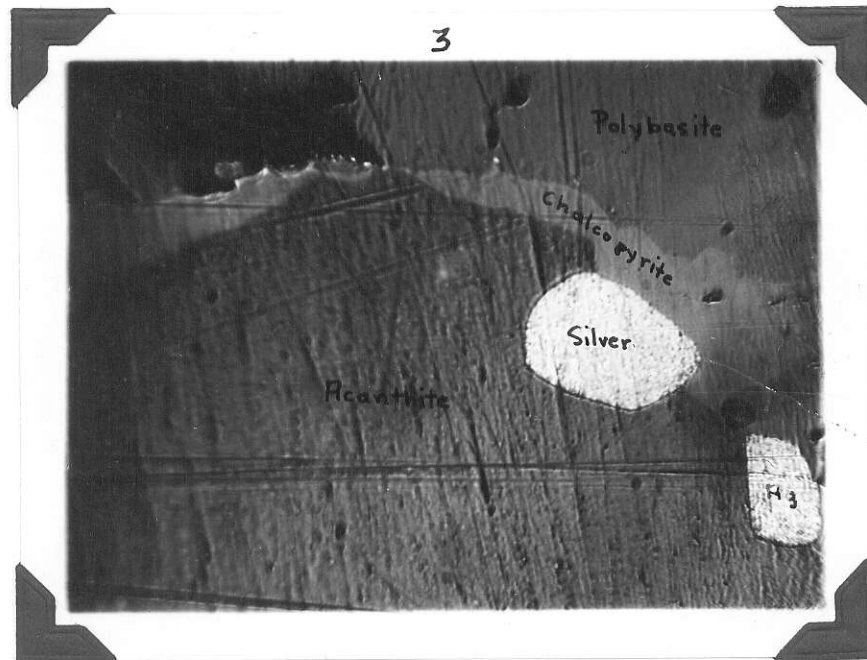


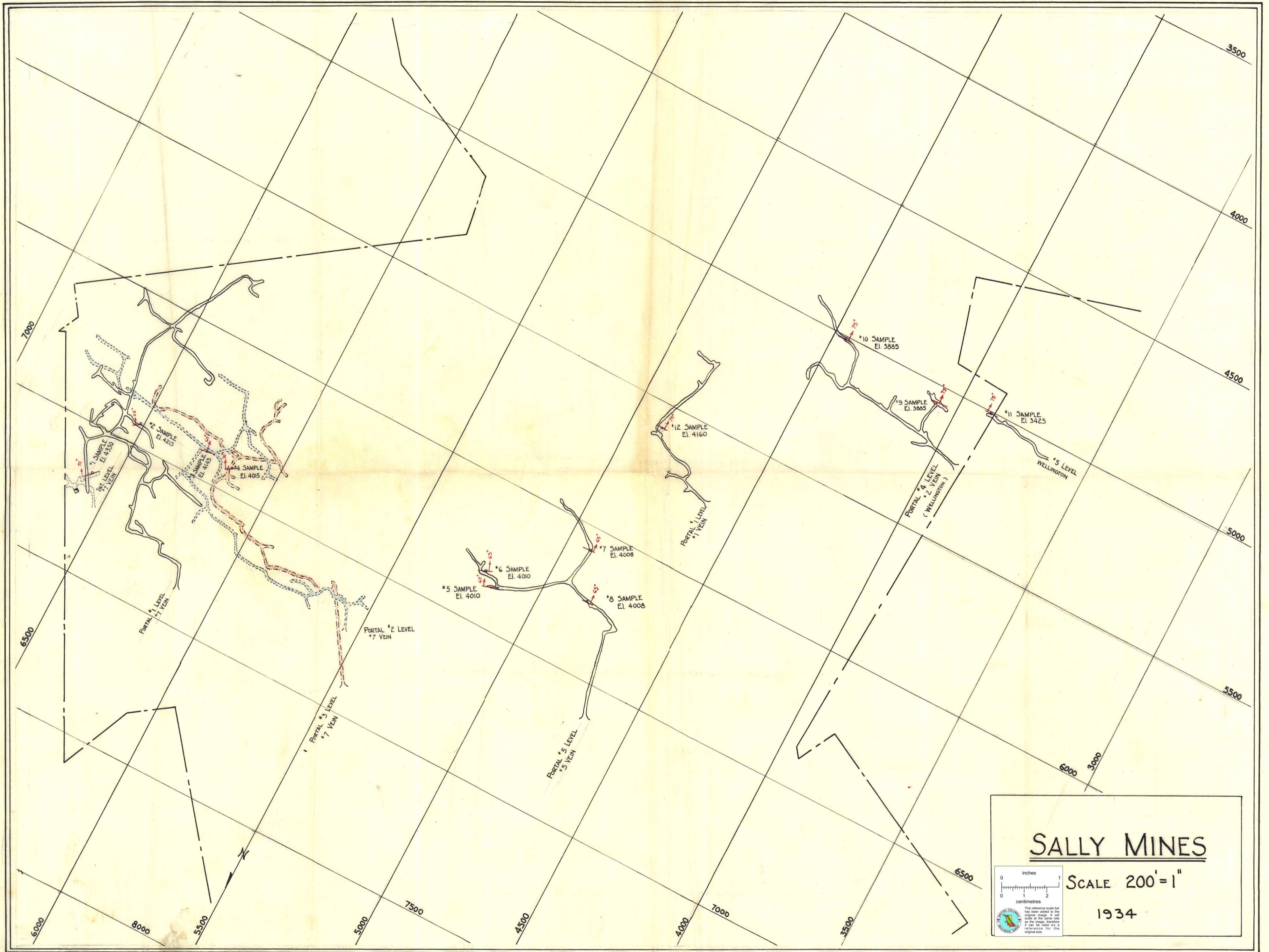
PLATE #3
Section 3-B

Part of the same area as picture No. 2 under higher magnification. Note all contacts are smooth. The native silver can be seen at the contact projecting into both the chalcopyrite and the acanthite. Note the rough, highly scratched surface of the acanthite.

BIBLIOGRAPHY

- (1) M. N. Short - Microscopic Determination of the
Ore Minerals, U.S.G.S. Bull 914 1940

- (2) Leopold Reinecke - Ore Deposits of the Beaverdell
Map Area G.S.C. Memoir 79 1915



SALLY MINES

SCALE 200' = 1"

1934

