Leaves little to be desired.

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MINERALOGRAPHIC STUDY OF ORE FROM THE SILBAK PREMIER MINE, BRITISH COLUMBIA

A report
submitted in partial fulfilment of the course
in Geology 409 in the Winter Session 1951-1952 at the
University of British Columbia

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April 16, 1952

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April 16, 1952

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Dear Sir:

I have the pleasure of submitting this report, MINERALOGRAPHIC STUDY OF ORE FROM THE SILBAK PREMIER MINE, BRITISH COLUMBIA, in partial fulfilment of the course in Geology 409 in the Winter Session 1951-1952.

Very truly yours
Wilfred E. Atamanchuk
Wilfred E. Atamanchuk

ACKNOWLEDGEMENTS

The writer wishes to thank Dr. R.M. Thompson, Assistant Professor of Geology, under whose supervision this study was made, for advice and assistance in identifying the minerals. Thanks are also due Professor Warren for valuable personal information and Dr. W.H. White for the specimens studied. Mr. J.A. Donan kindly assisted in the cutting and mounting of specimens for microscopic examination. To him, and to Mr. J.J. McDougall, laboratory assistant in the Department of Geology, the writer extends his thanks.

SUMMARY

A detailed microscopic examination of ten ore specimens from the Silbak Premier Mine was carried out. The following report includes, in addition to the results of the present study, a brief account of the history, geological environment, and factors of ore localization of the mine.

The principal minerals reported are, in order of abundance, pyrite, sphalerite, galena, chalcopyrite, polybasite, argentite, pyrargyrite, tetrahedrite, electrum, native silver and native gold, in quartz and calcite gangue. Pyrite, gold, sphalerite and chalcopyrite were deposited early in the cycle of mineralization, while galena and the silver minerals were deposited later. The main textural relationship of the silver minerals is mutual boundaries, and simultaneous deposition is suggested.

The following conclusions were reached:

(a) On the evidence of solid solution and inversion, the ores were deposited at a temperature ranging from 179°C to less than 550°C.

(b) Character of the silver minerals appears to be that typical of a epithermal to mesothermal hypogene silver ore. Evidence indicating supergene enrichment was not found.

(c) The number of specimens studied does not

permit general conclusions on vertical zoning of minerals. It appears, however, that tetrahedrite and electrum are fairly uniformly distributed in quantity and grain size throughout at least the upper 500 feet of the workings.

(d) Pyrargyrite and gold occur in sections taken from the higher levels while native silver and argentite were seen only in one section from about the 1580 level.

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Introduction

Location

The Silbak Premier Mine is situated in the Portland Canal Mining Division of northern British Columbia. The mine lies in the Salmon River Valley on the western slope of Bear River Ridge and fifteen miles by road north of Stewart which is at the head of Portland Canal. The proximity to tide water at Stewart has contributed to the success and longevity of the mine.

History of Mining Activities[6]

The Silbak Premier property ranks among the foremost producers of gold and silver in the province. The property was worked originally as a high grade gold-silver mine but, as the grade of ore declined, lead and copper were recovered and recently, zinc and cadmium. Production has

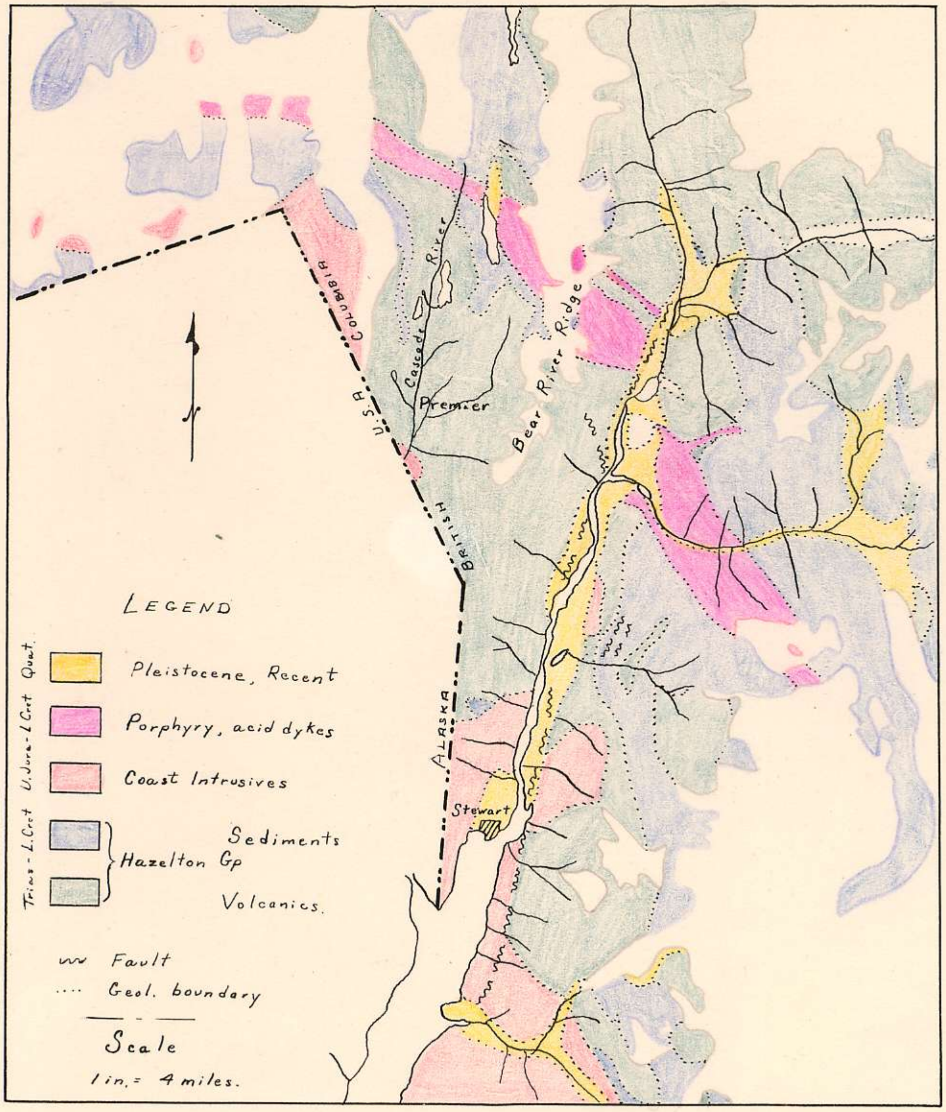


Figure 1: Geologic Map of Portland Canal Area, B.C. (after Hanson[4])

been almost continuous since 1918.

The present property includes the adjoining former Premier, B.C. Silver and Sebakwe properties. The original Premier claims were staked in 1910 and some exploratory work was begun in 1911. Active development was not undertaken, however, until 1917. From 1919 to 1935 the mine was operated by the Premier Gold Mining Company. By 1935, with workings at a depth of about 700 feet, the ore apparently ran out. At this time Silbak Premier Mines, Limited, was incorporated and now operates the consolidated properties using the Premier mill and plant. Further development extended the operations to a depth of over 1300 feet. At present workings are being carried into the adjacent Premier Border property which is being mined jointly with Premier Border Gold Mining Company.

Present grade of ore is (1947): Gold, 0.22 oz. per ton; Silver, 1.49 oz. per ton; Lead, 2.25 per cent; Zinc, 3 per cent. Total production to 1947 was 1,736,248 oz. in gold, and 36,703,762 oz. in silver.

General Geology

Geologically, the Silbak Premier mine is located in Mesozoic rocks near the eastern contact of the Coast Intrusions. The table of formations, as outlined by Hanson,[4] is given below.

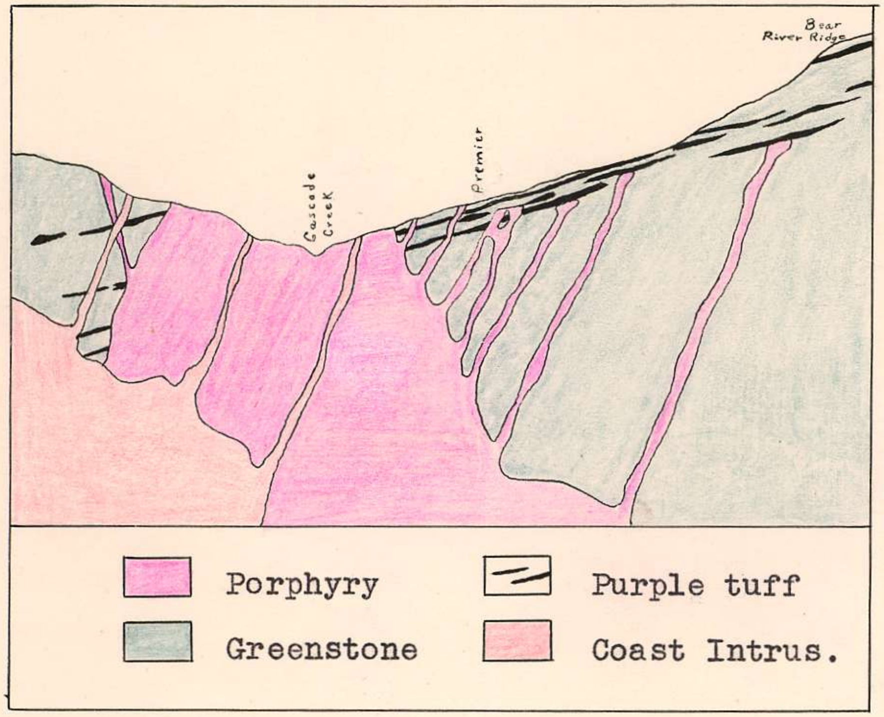


Figure 2: Idealized Vertical Section of Premier Area[5]

TABLE OF FORMATIONS
(Table 1)

Quaternary	Recent and Pleistocene	Gravel, sand, silt, Marine clay, Glacial drift.
Tertiary		Basaltic lava flows.
Jurassic - Early Cretaceous		Dykes.
		Granodiorite.
Triassic? - Jurassic and Early Cretaceous	Hazelton Group	Argillite, quartzite, Greywacke, tuff, Breccia, felsite, Augite porphyrite, Gabbro, amphibolite, Fedspar porphyry.

The important rock types in the mine are the Hazelton volcanic sequence (originally described by McConnell as the Bear River formation) and the Premier porphyry of granodiorite composition. These rocks form the northeastern limb of a northwesterly plunging open syncline which has been complicated by cross-folding and shearing.

A purple tuff horizon occurs as narrow, irregular, and somewhat discontinuous bands blanketing the orebodies and following the slope of the land surface. The porphyry intrudes the volcanic series in irregular sill-like bodies (see Figure 2). Both tuff and porphyry are of great importance in the localization of ore.

Dyke-like apophyses of quartz diorite from the main mass of the intrusions cut the volcanics and porphyry. They strike northwesterly and dip steeply to the southwest. Their relation to the orebodies is unknown. Smaller dioritic and lamprophyre dykes, having the same attitude, were intruded during or after the period of mineralization.

Two main fracture systems are recognized at the mine. One trends roughly parallel to the eastern contact of the coast intrusions, the other is at right angles, N50°E and dips about 60° to the northwest. The latter system follows a porphyry intrusion near a tuff-porphyry contact.

Relation of Mineralization to Geology and Structure

The ore controls are the main fracture systems, the porphyry intrusions, and, locally, lamprophyre and dioritic dykes.

Mineralizing solutions, originating in the Coast Intrusions, have followed the NE and NW shear zones. At intersections of these zones, where fracturing and permeability have been increased, the mineralization is particularly intense. Wall rocks have been silicified and replaced by massive sulfides, chiefly pyrite, sphalerite, and galena.

The competency of the porphyry relative to that of the volcanic series has influenced the localization of the ore. The rock is brittle and when stressed has been finely fractured, thereby providing channelways for the mineralizing solutions. Tuff and greenstone, on the other hand, have yielded, by incipient flow or internal shear and have retained their compactness. Near the surface the purple tuff caps the porphyry and generally the orebodies. The ore grades laterally and downwards from silicified porphyry zones into less siliceous rock with much pyrite and with low values.

In the West ore zone on B.C. Silver property, the porphyry and tuff are absent and lavas, intruded by lamprophyre and dioritic dykes are the main rocks. Narrow mineralized zones are found along contacts of the dykes and along fractures occupied in places by dyke rocks.

Briefly then, the main ore zone trending N50°E follows a principal fracture system along a well-defined porphyry-tuff contact. The size and position of the orebodies is controlled by the intensity of shearing in favorable porphyry rocks. The vertical range of the orebodies is about 1300 feet, those of importance having been found above the No. 6 level (at an elevation of 790 feet above sea level).

Purpose and Scope of this Study

The examination of Silbak Premier ore was undertaken in the expectation that some contribution might be made to the known information on mineralogy and ore deposition at the mine. Previously the mineralogy of the old Premier workings was studied by W.D. Burton and that of the Northeast Zone by W.H. White. The conclusions arrived at by each of these workers do not entirely agree, particularly in regard to the nature and extent of supergene silver enrichment. In the present study evidence to confirm ~~with~~ either results was especially sought.

The specimens were collected from the old Premier mine by Dr. White and ten polished sections were prepared. The specimens were examined megascopically and detailed microscopic study was made of the sections. The laboratory procedure consisted of examination under medium and high power (with oil immersion), in plane and polarized light, using standard laboratory microscopes. Minerals were identified by their physical properties (color, texture, hardness, sectility, anisotropic colors) and by microchemical and etch tests. Standard etch reagents used were $HgCl2$, KOH, KCN, HCl 1:1, $FECl_3$, and HNO_3 1:1. A spectrographic analysis of electrum was made by Dr. R.M. Thompson.

Megascopic Description

In hand specimen the ore is typically massive sulfides in silicified popphyry rock. The porphyry is greenish-grey, brittle and has a dense to fine-grained texture. In places it is altered to chlorite, calcite and sericite. Massive quartz and crystalline calcite are frequently present in veins and masses. In order of abundance, the metallic minerals observed are pyrite, sphalerite, galena, pyrargyrite, chalcopyrite and tetrahedrite. They occur in fine grains (pyrite is often course) in masses or disseminated throughout the wall rock, replacing the porphyry and gangue minerals or filling fractures. Sphalerite is medium to dark brown and

DISTRIBUTION OF MINERALS
(Table 2)

SECTION	2	3	1	5	6	7	8	9	10	4
ELEVATION (app.)	2000'	2000'	1775'	1750'	1750'	1580'	1580'	1580'	1580'	1070'
Pyrite	X	X	X	X	X	X	X	X	X	X
Sphalerite	X	X	X	X	X	X	X	X	X	X
Galena	X	X	X	X	X	X	X	X		X
Chalcopyrite	X		X	X	X	X	X	X	X	X
Polybasite	X	X	X	X	X	X		X		
Argentite									X	
Pyrargyrite	X	X			X					
Tetrahedrite		X					X	X		
Electrum	X	X	X	X	X		X	X		
Native Silver									X	
Native Gold			X	X	X					

galena characteristically shows well-developed cleavage. Individual specimens are briefly described in the appendix.

Microscopic Description

The following list gives, in order of abundance, the minerals identified in polished sections

- Pyrite
- Sphalerite
- Galena
- Chalcopyrite
- Polybasite
- Argentite
- Pyrargyrite
- Tetrahedrite
- Electrum
- Native Silver
- Native Gold

- Gangue minerals
    - Quartz
    - Calcite

Pyrite - FeS_2

Pyrite varies in amount from a few grains in Section 3 to about 70% in Section 1. It occurs generally as subhedral grains in quartz and calcite gangue which has been partly or entirely replaced by sulfides. Frequently they are euhedral, showing the pyritohedral and cubic form with striated faces.

The grains are often finely fractured and fractures are filled with gangue and later sulfides. Pyrite is commonly corroded by galena and sphalerite and often only a rim of the original mineral remains. Vein replacement along grain boundaries and more or less euhedral grains of quartz partially included in the pyrite has been noted. Textural relations indicate that pyrite was the first formed of the metallic minerals.

In polished section pyrite is recognized by its pale brass yellow color, which varies according to the orientation of the grain and then often shows faint anisotropism. Rough pitted surface, hardness E, and usual isotropism are distinctive.

Sphalerite - ZnS

Sphalerite, second in abundance, is also found in all sections. The mineral is dark grey with a pitted surface which takes a good polish. It is generally associated with galena and veins and replaces gangue minerals and pyrite. Sphalerite is itself replaced by later sulfides and occurs as islands in masses of galena. An interesting and significant relationship with chalcopyrite is discussed under that mineral.

Sphalerite presumeably free of pyrite was found to contain iron but no cadmium. Internal reflection is not pronounced except along deep fractures. Polysynthetic twinning is universally present.

Galena - PbS

Galena occurs in masses up to 3 mm. across, normally showing triangular pitting and cubic cleavage, ~~with~~ hich, in places has been distorted by movements subsequent to crystallization. Tetrahedrite, polybasite and electrum are commonly but not exclusively associated. Their relations are mutual boundaries, the intimacy suggesting co-deposition. Galena is seen veining pyrite, and calcite and is therefore later. Relations with sphalerite are usually smooth contacts or "island-and-sea" texture and simultaneous deposition or replacement by galena is suggested. Slight evidence of veing of sphalerite has been noted. Microchemical tests revealed no silver was present in galena.

Chalcopyrite $CuFeS_2$

Chalcopyrite is found in nearly all sections in minor amount. It is most frequently associated with sphalerite as inclusions varying in size from barely visible specks to smoothly bounded blebs up to 130 microns. The minute specks have undoubtedly exsolved from solid solution in sphalerite. The distribution is generally irregular, but in a few places, the specks are aligned along the twin planes ?(0,111) of the sphalerite. Often the blebs are concentrated in a band near the edge of the sphalerite grain. This evidence indicates a simultaneous and possibly slightly later deposition of chalcopyrite with respect to sphalerite. Chalcopyrite is also found not in association with sphalerite but with galena and argentite (Figure 9), and has mutual boundaries with these minerals. Chalcopyrite and argentite appear to be simultaneous replacing calcite along cleavage planes.

Yellow color, isotropism and non-sectility distinguish chalcopyrite.

Polybasite - $8Ag_2S \cdot Sb_2S_3$

Polybasite occurs as regular grains in galena chiefly but also in sphalerite and gangue minerals. The grain size varies up to 300 microns. The mineral usually shows smooth, straight or curving outlines in galena and irregular, ragged outlines in gangue. It has been deposited apparently at the same time as galena. A not unusual occurrence is illustrated in Figure 11, where polybasite, in association with tetrahedrite, galena, chalcopyrite or electrum, forms a rim around a partially replaced pyrite grain.

Polybasite is recognized by a greenish-grey color and anistopric colors of yellow-green to violet (or deep blue).

Argentite - Ag_2S

Argentite is observed in Section 10 only. It occurs in veinlets up to 1 mm. wide, replacing calcite which veins quartz. The grains show straight angular outlines. Argentite has apparently been deposited simultaneously with chalcopyrite and may be replaced by native silver.

The mineral is isotropic, and therefore isometric and represents the high-temperature form of Ag_2S. It is grey and very sectile. The etch test with HCl was not distinctive. The halo which commonly forms was often absent or very faint in several tests.

Pyrargyrite - $3Ag_2S.Sb_2S_3$

Pyrargyrite occurs in Sections 2 and 6 usually in association with polybasite. The normal occurrence is rather discontinuous, irregular veins in quartz and calcite, which seems to be completely shot through with the ruby silver. The gangue assumes a bright red color under crossed-nicols due to the extreme internal reflection of the pyrargyrite. The average grain size is about 20 microns. The largest grain, 100 microns, was observed in section 6, (Figure 7).

The texture suggests core replacement of galena by polybasite and later pyrargyrite. A possible reversal of the order of deposition, that is, pyrargyrite first, is unlikely. The sharp and smoothly curving boundaries would indicate contemporaneity. However, pyrargyrite has been seen in other ores veining and replacing polybasite and having smooth, even outlines. The boundary relations also indicate a hypogene rather than supergene replasement.

Pyrargyrite was confirmed by microchemical tests in which no arsenic was fennd. The mineral has a pale-blue color, is anisotropic and has a bright cherry-red internal reflection. Etch tests agreed with those listed by Short.

Tetrahedrite - $Cu\ (Fe, Zn, Ag)_{12} \cdot Sb\ (As)_4 \cdot S_{13}$

Tetrahedrite is always associated with galena and usually with polybasite. It normally occurs as smoothly bounded grains in galena in contact with pyrite or sphalerite. The grain size varies from regular blebs about 10 microns isolated in galena, to masses up to 35 microns in diameter. Tetrahedrite appears to be contemporaneous with polybasite and galena.

The color is grey with a faint pink tinge; hardness D, isotropic; surface pitted but takes a bright polish. Because of the intimate association with polybasite, the mineral was not tested for silver. Etch tests were negative to all reagents.

Electrum - Au, Ag

Electrum, occurs in all sections and in association with all minerals reported. It is found most commonly, however in galena and in contact with pyrite. It occurs as regular bounded inclusions in chalcopyrite, and sphalerite, and in fractures in calcite and quartz. The average grain size is about 15 microns, and the largest is about 40 microns.

Electrum is very sectile and is pale yellow, the color varying slightly depending on the color of the host mineral. In dark-colored minerals such as sphalerite and gangue the color tends to creamy-white, very like that of native silver. It is possible that some of the silver has been identified as electrum. Etch tests do not distinguish the two minerals. $FeCl_3$ reacts positively for electrum in disagreement with Short. This test is identical with that for native silver.

Reagent	Locality ? Electrum (Short)	Electrum (Premier)	Native Silver (Short)
$HgCl_2$	+	+	+
KOH	-	-	-
KCN	+	+	±
HCl	-	-	±
$FeCl_3$	-	+	+
HNO_3	+	+	+

A spectrographic analysis of a sample of electrum by Dr. Thompson showed silver and copper but no gold. Microchemical tests were also negative for gold. A gold test is apparently difficult to obtain by this means possibly because of interference by copper. On the basis of color and similarity to electrum identified in other sections of the mine, the mineral is accepted as electrum. Dr. White reports the composition as 65% Au: 35% Ag, corresponding to a volume ratio of 1:1.

Native silver - Ag

Silver is identified in Section 10 and is probably present in other specimens. It is found associated with chalcopyrite, argentite, replacing calcite along cleavage planes and possibly argentite. The grains average about 30 microns in size.

Native gold - Au

Gold is found in isolated blebs in pyrite or in stringers with galena replacing pyrite along the grain boundaries. The maximum grain size is about 15 microns. Where occurring in isolated blebs, gold may be earlier than or contemporaneous with pyrite; in stringers it is later, having been deposited with or after galena.

Gold is distinguished from electrum by its yellower color and pitted surface. Etch tests are as given in Short - all reagents negative except KCN, and aqua regia.

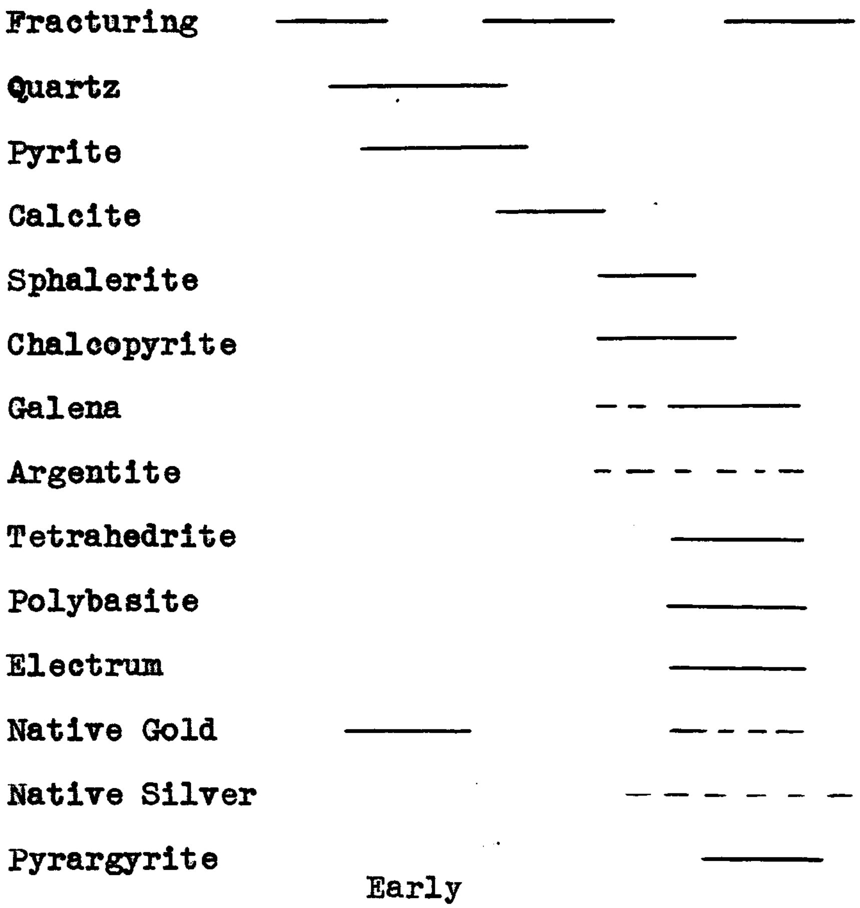
Gangue Minerals

Quartz is the principal gangue mineral and seems to have been deposited prior to, or simultaneous with, the deposition of pyrite. A second generation of quartz has come in after the fracturing of pyrite and original quartz. The earlier gangue mineral is often seen in euhedral crystals in pyrite or younger quartz and usually has a smoother, less pitted surface than that of later period. Later quartz is massive and heals fractures in pyrite.

Calcite is less abundant and decidedly later than quartz. The mineral veins the quartz and is generally replaced by later sulfides in preference to quartz. Limonite is noted in several sections.

Paragenesis

The age relations are shown in the accompanying table.



Fracturing has occurred before the emplacement of ore minerals and is also evident post-pyrite and post-galena deposition.

The porphyry was extensively fractured and replaced by quartz. Pyrite and gold were introduced at this stage or later. Fracturing of pyrite occurred with further deposition of quartz, and probably pyrite. Some calcite must have accompanied the quartz. Later minerals filled fractures and replaced preceding minerals in complicated overlapping periods of deposition.

Conclusions

The conclusions arrived at from the present study agree, with minor changes in the paragenetic sequence, with those of Dr. W.H. White.

Temperature of Deposition

The upper and lower temperature limits are indicated respectively by the unmixing of chalcopyrite in solid solution with sphalerite and the presence of isometric argentite. At a temperature above 350°C to 400°C chalcopyrite is soluble in sphalerite to an extent of about 10 percent and below this temperature ex-solution takes place. Chalcopyrite exsolves as minute blebs or blades scattered throughout the sphalerite often along the (111) direction of the host but more frequently in a more or less random distribution giving an "emulsion" texture. Such an intergrowth of sphalerite in chalcopyrite (occurring at about 550°C) is not present indicating that the highest temperature reached was less than 550°C. and greater than 350°C. to 400°C.

The presence of isometric argentite indicates a minimum temperature of 179°C. Natural isometric argentite occurs at temperatures above 179°C. and represents the high temperature form of Ag_2S. Below this temperature inversion to orthorhombic acanthite takes place.

Mineralization - Hypogene or Supergene?

No evidence has been found to indicate definitely the presence of supergene enrichment of silver minerals. Textural relations and paragenesis appear to indicate a normal hypogene sequence of silver ore mineralization, eg. galena, polybasite, pyrargyrite, native silver, etc. Limonite and coatings of covellite occur near the surface and are the only indicators of secondary deposition.

Vertical Zoning of Minerals

The small number of specimens studied gives a very incomplete picture of the vertical distribution of minerals. It appears, however, that tetrahedrite and electrum are fairly uniformly distributed in quantity and grain size throughout at least the upper 500 feet of the workings. Pyrargyrite and gold occur in sections taken from the higher levels while native silver and argentite were seen only in one section from about the 1580 level.

KEY TO FIGURES 4 TO 11.

pe	Pyrite
sp	Sphalerite
g	Galena
ch	Chalcopyrite
t	Tetrahedrite
ar	Argentite
el	Electrum
s	Native silver
go	Native gold
po	Polybasite
pa	Pyrargyrite
q	Quartz
ca	Calcite

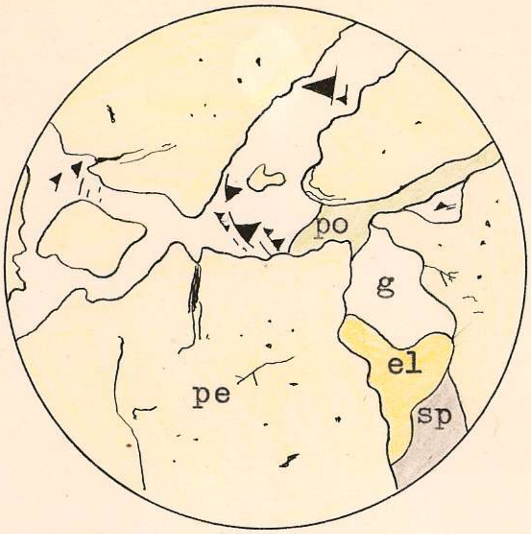


Figure 4: Occurrence of electrum in association with galena and sphalerite. (1) x60

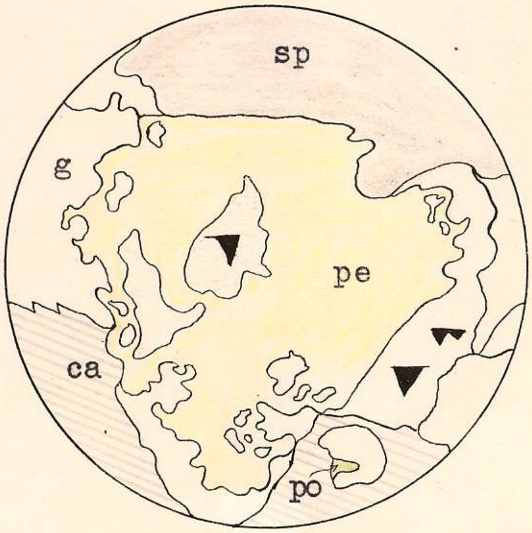


Figure 5: Corrosion of pyrite by galena and sphalerite. (7) x50

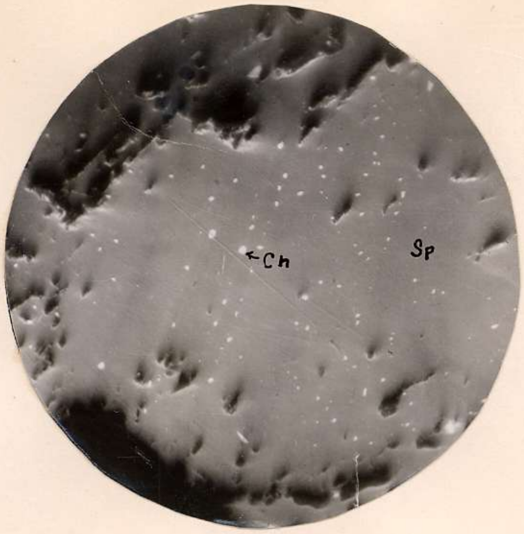


Figure 6: Ex-solution blebs of chalcopyrite in twin planes o(111), of sphalerite. (8) x120

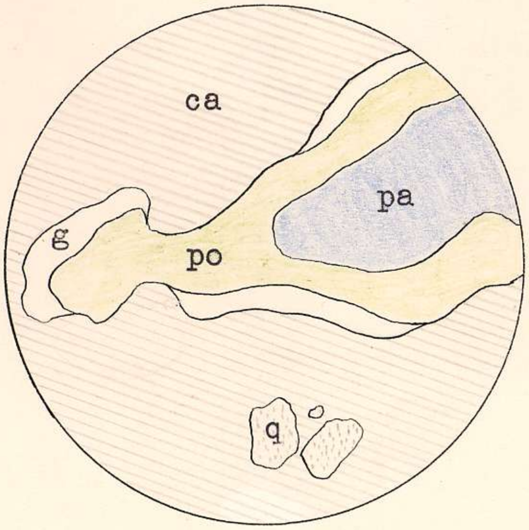


Figure 7: Core replacement of galena successively by polybasite and pyrargyrite. (6) x 75

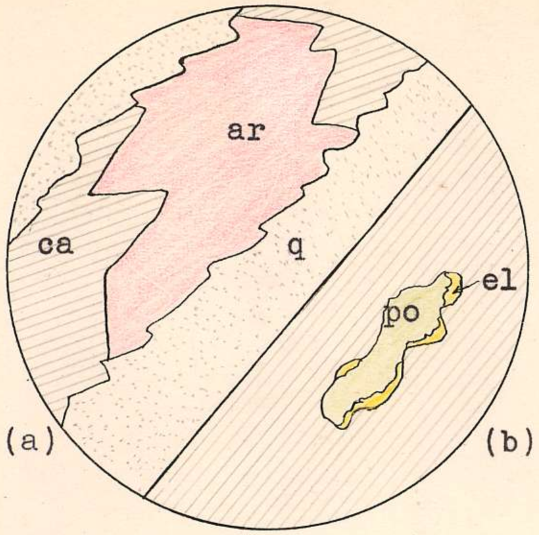


Figure 8: Calcite, partially replaced by argentite,
(a) veining massive quartz. (10) x30
(b) Polybasite rimmed by electrum (?). (5) x120

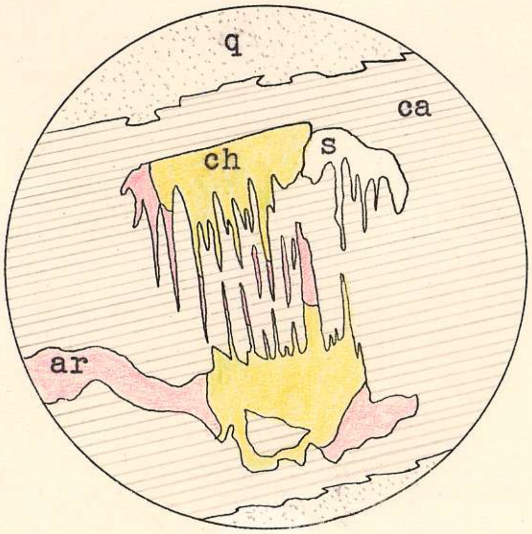


Figure 9: Chalcopyrite, argentite and native silver replacing calcite along cleavage planes. (10) x120

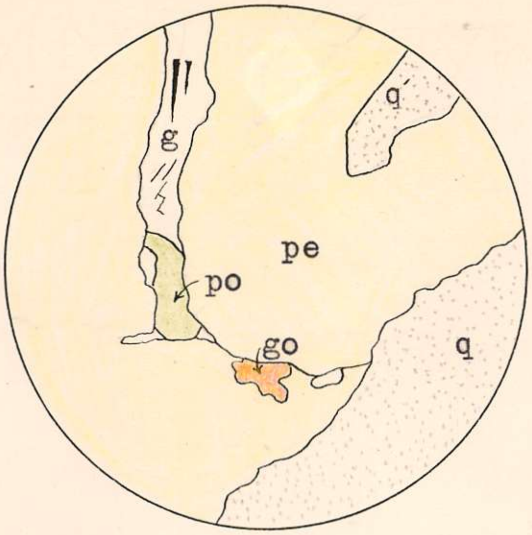


Figure 10: Typical occurrence of native gold in pyrite. Two ages of quartz are shown (q´is the earlier). (5) x75

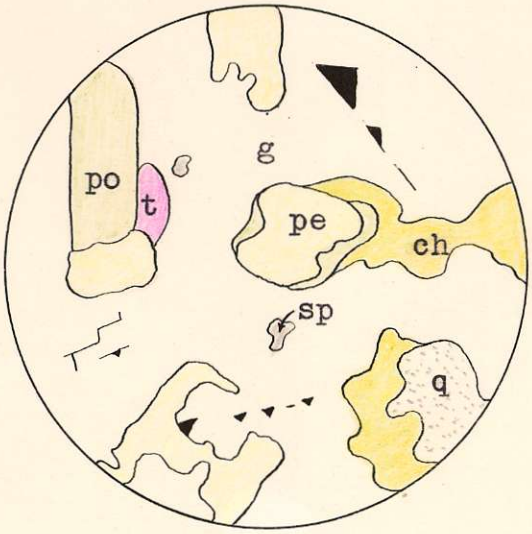


Figure 11: Usual occurrence of tetrahedrite associated with polybasite and galena and in contact with pyrite. (7) x60

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Appendix

Description of Individual Specimens

Specimen 1

Location - 250 Sub-level - 3JH Drift

Assay - About $100

-Massive sulphides consisting of about 75 percent pyrite, 10 percent sphalerite, and 5 percent galena in quartz and calcite gangue. Pyrite is medium-grained, the largest grain about one-eighth inches in diameter. The grain size decreases as the sphalerite content increases, suggesting replacement by the sphalerite. Galena is disseminated throughout.

Specimen 2

Location - 1Q Stope

Assay - 3 oz. Gold; 300 oz. Silver

-Silicified porphyry wall rock with disseminated grains of pyrite, galena, and sphalerite. Glossy tetrahedrite, which has been smeared by shear movement is present. A weak schistosity has been developed indicating a position near a shear zone. Quartz occurs as stringers in the porphyry.

Specimen 3

Location - 1Q Stope

Assay - 3 oz. Gold; 500 oz. Silver

-Highly silicified porphyry shot through with hair-like stringers of deep red ruby silver with a red streak (suggesting pyrargyrite). A few disseminated grains of pyrite are observed, and appear concentrated along fractures in massive white quartz and porphyry.

Specimen 4

Location - 5B East Stope - 50 feet below 4L

-Fine grained, massive sulfides. Bands of pyrite mainly and galena, sphalerite with minor pyrite are apparent. The gangue, is quartz mainly. Pyrite forms about 65 percent of specimen, the remaining sulfides 35 percent.

Specimen 5

Location - 247 X-Cut -(290 C-Stope
#2 Sub-level above #2 Level

Assay - 23.2 oz. Gold; 950.16 oz. Silver

-Coarse grained sulfide replacement in siliceous porphyry, subhedral pyrite grains, up to ¼ inch in size, compose 30 percent of specimen. A black sooty coating of covellite, possibly, covers some of the grains. Calcite is present.

Specimen 6

Location - 238 Raise #2 Sub-level

Assay - About $400

-Medium grained pyrite concentrated in a band, 1 to 1⅛ inches wide in crystalline calcite, and chloritized porphyry rock. Pyrite, galena, and sphalerite are the main sulfides. The black substance, Covellite?, occurs here coating the fractures and penetrating the calcite in fine hair-like stringers.

Specimen 7 - 9

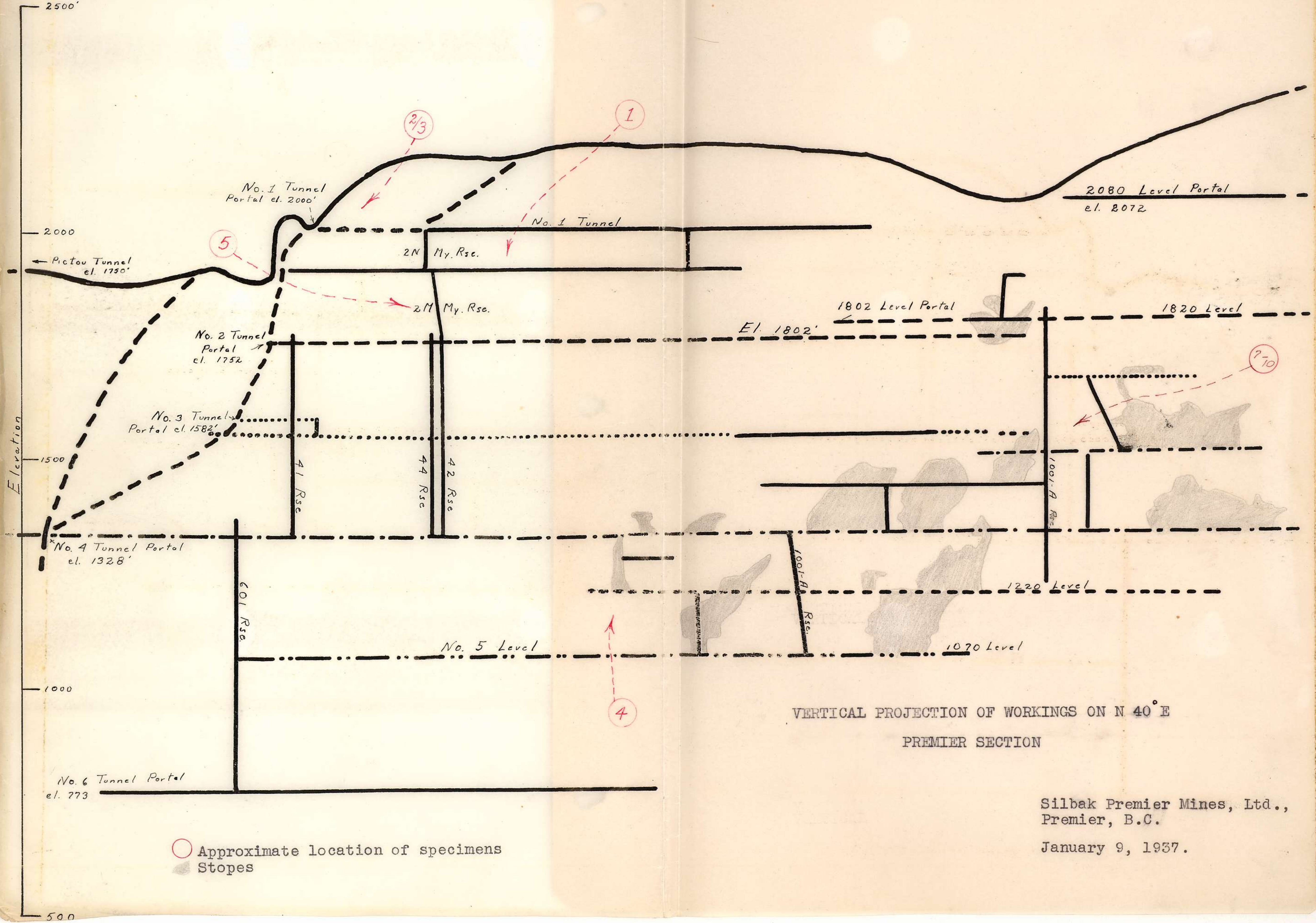
Location - 3 D Stope

-Fine grained sulfides in porphyry, and consisting chiefly of galena and sphalerite and pyrite (Specimen 8 is mainly massive sphalerite with veined chalcopyrite). Chalcopyrite is usually disseminated. Pyrite grains are about 1/16 inch in size. The sulfides show veining and replacement of calcite and porphyry.

Specimen 10

Location - 3 D Stope

-Dense, white, siliceous rock with fine dendritic stringers (up to 1/16 inch in thickness) of argentite. Pyrite and galena are also present.



VERTICAL PROJECTION OF WORKINGS ON N 40° E

PREMIER SECTION

Silbak Premier Mines, Ltd.,
Premier, B.C.

January 9, 1937.

○ Approximate location of specimens
▨ Stopes