A careful job but few minor
errors & omissions. Does
not say what impurities would be
contained in a lead conc., zinc
concentrate. 75%

MINERALOGRAPHIC REPORT ON THE SULLIVAN ORE

26/35

A report submitted in partial fulfilment
of the course in Geology 409 of Fourth
year Applied Science at the University
of British Columbia.

A.M. SCOTT

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The University of British Columbia

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Introduction

The Sullivan mine, located at Kimberley in southeastern British Columbia, is one of the largest siver-lead-zinc mines in the world. The mine was discovered in 1892, but little work was done until 1900. In 1903 a smelter was started, but closed down in 1907 because of metallurgical difficulties. In 1910 the Consolidated Mining and Smelting Company of Canada took up their option of the previous year on the property. From then on the mine has operated continually. In 1945, 2,435,877 tons of ore (12) were treated. The concentrates contained 5,103, 027 ounces of silver, 172,473 tons of lead, and 146, 389 tons of zinc. Tin is also produced at this mine.

General Geology

As shown by the geological map (Fig. 1) the area is underlain by two late-Precambrian sedimintary formations:

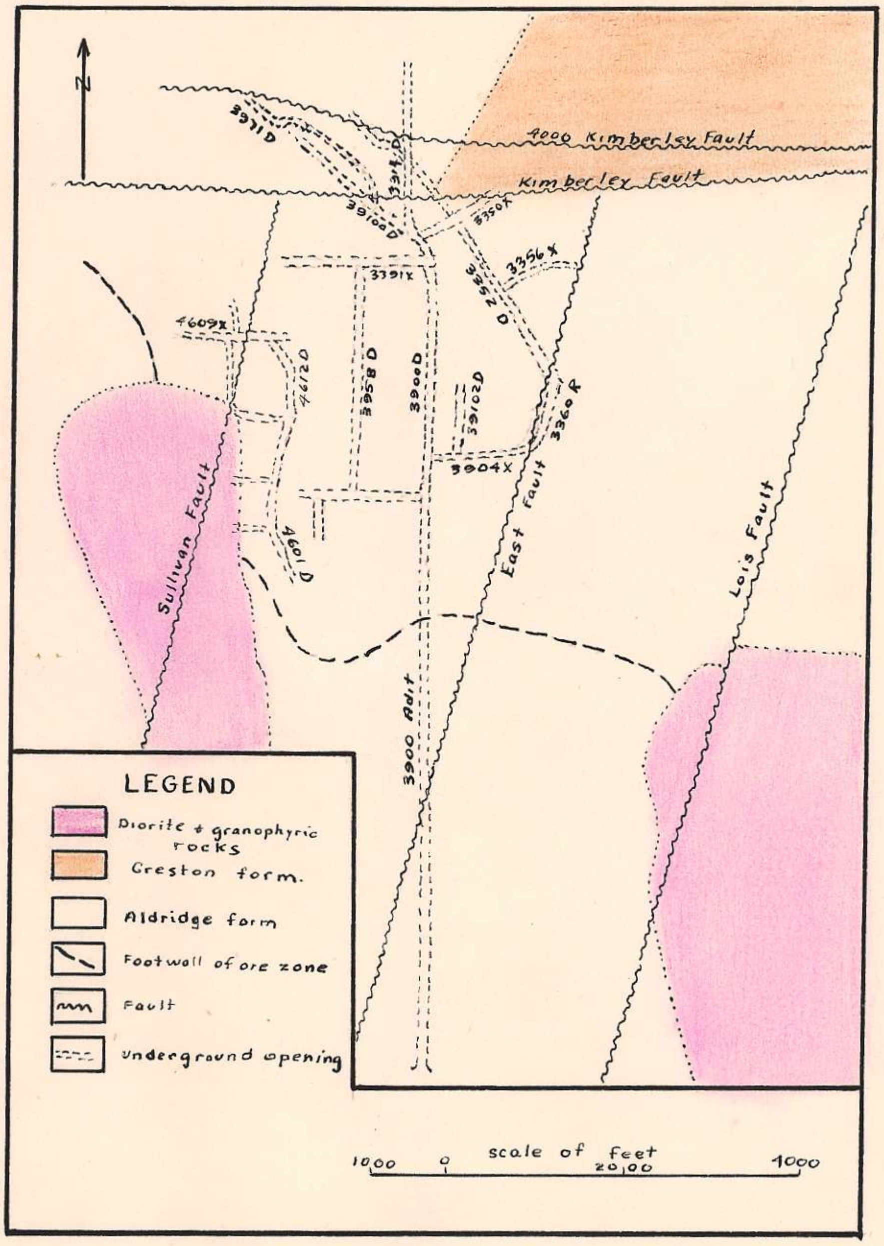

Fig. 1. Geological Sketch-map, Sullivan mine (12).

the Aldridge and the Creston. These formations dip about 30 E and are composed of argillite, siltstone and quartzite. Two large areas of diorite and granophyric rocks are also shown on the map. Swanson and Gunning (12) noted that small bodies of diorite are found in various places in the mine as dykes, sills and irregular, shaped masses. A mica lamprophyre occurs in the bed-rock type as thin dykes.

The area in the vicinity of the mine is on the east side of a broad anticline, the axis of which strikes nearly north. The anticline has a series of minor folds and a number of gentle warps.

The strata are broken by a number of faults of which the Kimberley fault is a major one. This fault has moved the Creston-Aldridge contact relatively 6 miles west on the north side of the fault. The other important fault structures are the Sullivan and the Lois (Fig. 1).

The base of the ore body, which is a sulphide replacement of certain beds, is underlain by conglomerate (Fig. 2) and is overlain by the base of upper quartzites. The ore is mainly in the lower part of the zone, however it occupies higher horizons south and up the dip. The ore does not always extend as high as the base of the upper quartzite.

Zoning

Swanson and Gunning (12) have the following to report on the arrangment of the ore: "In mining the upper levels, the orebody was found to be fairly continuous, although rather thin, above the 4,600-foot adit. A short

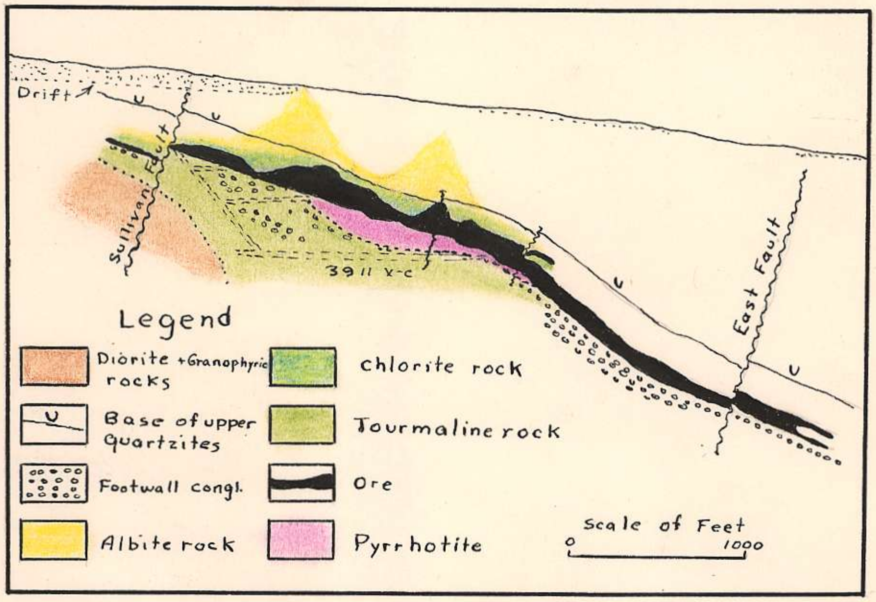

Fig. 2 Vertical east-west section, Sullivan mine (12).

distance below that level, the ore separated into two branches, called the South and North orebodies. The sufphide replacemant continues between these branches, but is almost entirely pyrite near the 4,600-foot level. This so-called central barren zone is irregular in outline, but can be roughly defined as an oval-shaped area lying between the 4,600 and the 3,900-foot levels and having a strike length of about 800 feet. Below the 3,900-foot level, which is the deepest of the present underground openings.

Pentland (4) notes the presence of a general zonal arrangement for the lead, zinc, and tin with respect to the central barren zone. The lead content is highest in the area adjacent to the central zone, and the ratio of zinc to lead gradually increases as the ore is followed away from this zone. The greatest concentration of tin within the main deposit lies near the outer part of the pyrrhotite of the central zone."

Megascopic Examination of the Ore

The specimens studied varied from pyrrhotite in black chert to massive galena and sphalerite. The minerals observed in the hand specimens were galena, sphalerite, chalcopyrite, pyrrhotite, pyrite, and a fibrous lead-grey mineral.

The majority of the specimens are characterized by a banded structure. Folds are noticeable and the mineralization follow these folds.

Galena varies from very fine grains to crystals five or more millimeters in diameter. Pyrrhotite is usually fine-grained, but some tabular crystals were observed to be one-half inch in length. Chalcopyrite on the whole is rare, but where it is observed is fairly massive up to one-half inch or more in diameter. Dark brown or black sphalerite is massive in most specimens often intermingled with pyrrhotite and pyrite. Cubic crystals of pyrite are noticeable throughout often occurring as fine-grained bands. The fibrous,
? tabular, lead-grey mineral (later identified as boulangerite) occurs with galena. A few needle-like laths

protrude into quartz.

The overall color of the specimens is a dirty grey with lenses and bands of bronze pyrrhotite. One specimen shows oxidation of a yellowish-brown color. The outer zone is a black chert with pyrrhotite in tabular crystals and irregular small bodies. The intermediate type is a fine-grained mixture of sulphides with bands of gangue throughout. The central zone has large crystals of galena and massive pyrite, however, the bands of galena, sphalerite, and pyrrhotite are still noticeable; but not as distinct as in the intermediate zone.

Microscopic Examination of the Ore

The minerals found by microscopic examination were as follows: pyrite, arsenopyrite, pyrrhotite, sphalerite, galena, boulangerite, and chalcopyrite. The minerals were identified with the aid of Short (10).

Pyrite (FeS_2)

Pyrite was recognized by its square, prismatic cross section; pale brass color; poor polish; unscratched by a neelé or hardness F. It was tarnished by HNO_3 and aqua regia. HCl, KCN, $FeCl_3$, KOH, and $HgCl_2$ were negative. The majority of the pyrite found in the polished sedtions was isotropic, but some crystals in section 8 showed weak anisotropism of light and dark grey. This was proven to be pyrite rather than marcasite since marcasite has strong anisotropism with colors of vivid ~~of~~ yellow, green, steel blue, and brown. This pyrite exhibited the usual square, prismatic cross section.

Rice (5) noted marcasite in the ore, however, none was found in the sections studied.

Arsenopyrite (FeAsS)

Arsenopyrite was identified by the diamond-shaped cross sections (Fig. 3) and color slightly whiter than galena. Arsenopyrite usually had a rough surface and could not be scratched by a needle. It is anisotropic; polarization colors yellow-green, brown and deep violet. HNO_3 stains differentially iridescent. HCl, KCN, $FeCl_3$, KOH, and $HgCl_2$ were negative.

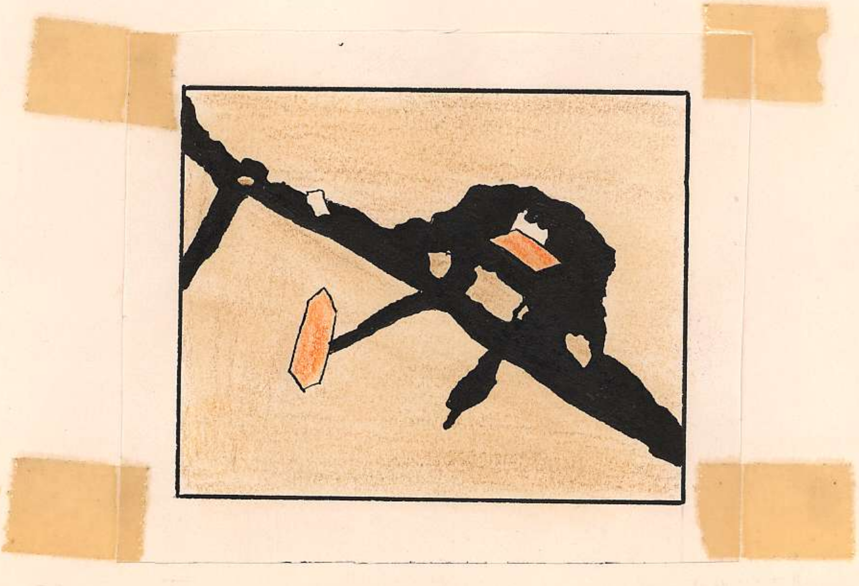

Fig. 3 Arsenopyrite in pyrite and gangue X 50

Pyrrhotite ($FeS_{1}+$)

Pyrrhotite was identified by being distinctly magnetic; pinkish cream color; hardness D-. It is anisotropic; polarization colors light grey, bluish to bluish-green grey, and brown. HCl was usually negative, but one applied drop turned yellow; fumes tarnished slightly on some sections. HNO_3 fumes tarnished section and stained light brown. KOH turned surface brown near periphery of drop. KCN, $FeCl_3$, $HgCl_2$ were negative. Some sections showed tabular crystals, but whether this was due to original crystals or pseudomorphic crystals in replacing biotite (12) the writer was unable to decide from the sections studied.

Sphalerite (ZnS)

Sphalerite was identified by resin-colored internal refection. At times this appeared orange to red. It was isotropic and had a grey color, but appeared bluish-grey when it was next to galena. Hardness was C. HNO_3 fumes tarnished; some effervescence was observed. Aqua regia effervesced and stained dark brown to black. HCl, KCN, $FeCl_3$, KOH, and $HgCl_2$ were negative.

Most of the sphalerite is actually marmatite, recognizable by the brown-black color. A microchemical test yielded iron.

Galena (PbS)

- Galena was recognized by cubic cleavage and triangular pits; galena white color; hardness B; and isotropism. $FeCl_3$ stained iridescent in most areas. HCl tarnished iridescent. HNO_3 stained black and gave off H_2S fumes. KCN, KOH, and $HgCl_2$ were negative.

Boulangerite ($5PbS.2Sb_2S_3$)

Boulangerite was not easily identified, in fact it was only after careful observation that a difference in color was seen in the galena. When the eye became use to the difference, it could be seen that boulangerite was greyer than galena. Also no pits or cubic cleavage were noticeable, but tabular or elliptical bodies were common (Fig. 4). The hardness was B. Boulangerite has strong anisotropism with polarization colors whitish-grey, steel blue, brownish grey, and dark grey. HNO_3 effervesced slightly with the surface staining black. HCl tarnished on some sections. $FeCl_3$, KCN, and $HgCl_2$ were negative. KOH etched and stained differentially iridescent on some of the crystals, while leaving other crystals unaltered. This was repeated many times since Short (10) indicates that KOH does not stain boulangerite, but stains jamesonite ($4PbS.FeS.3Sb_2S_3$) which can be readily mistaken for boulangerite. Microchemical tests

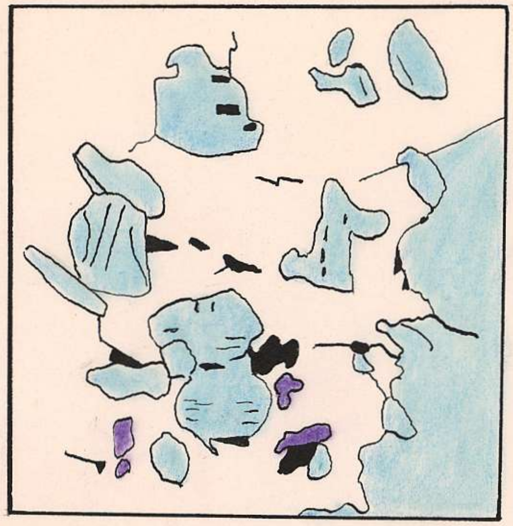

Fig. 4 - Boulangerite in Galena - White galena, blue - boulangerite, purple - sphalerite, black - gangue, X 50 .

were made from the crystals which had reacted with KOH and though lead and antimony were readily found, no iron was discovered. The section was cut so that most of the boulangerite crystals were shown with their short axes. However, where a long tabular crystal was found there was no basal cleavage to identify it as jamesonite. The hand specimen was look over carefully again, but it showed no basal cleavage; therefore, it can be concluded that the mineral is boulangerite rather than jamesonite.

Chalcopyrite ($CuFeS_2$)

Chalcopyrite was recognized by its brass yellow color; hardness C; and weak anisotropism. HNO_3 fumes tarnish. Aqua regia fumes tarnished differentially. HCl, KCN, $FeCl_3$, KOH, and $HgCl_2$ were negative.

Tin

Cassiterite (9) occurs in the ore, but was not seen in the sections studied.

Silver

Silver occurs as mentioned previously, but no silver mineral was found. Figure 5 shows a part of the section in which an assay was run. The assay contained

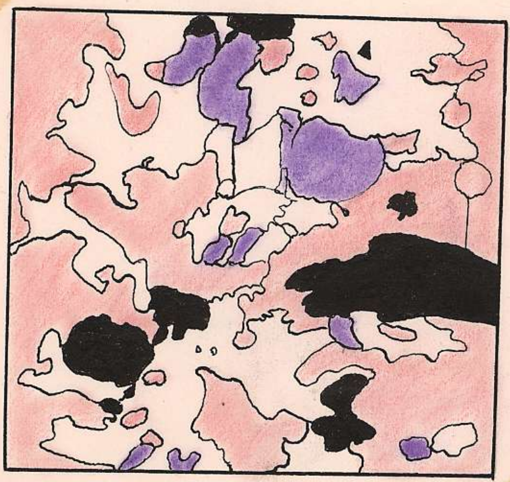

Fig. 5 Galena replacing pyrrhotite, X 50
Galena - white, pyrrhotite - carmine,
sphalerite - purple, gangue - black.

21.5 ounces of silver, 43.7% lead, and 20.0% zinc. Section 2 illustrates the ore from which this assay was run. We can conclude that the silver is in solid solution with galena, since Edwards(3) states that a maximum of 30 ounces of silver will tend to be homogenous in galena.

Paragenesis

The order of deposition was as follows: arsenopyrite, pyrite, pyrrhotite preceding and contemporaneous with sphalerite, sphalerite, chalcopyrite contemporaneous with sphalerite and perhaps later, galena, and boulangerite.

Arsenopyrite has formed diamond-shaped crystals in pyrite (Fig. 4). Pyrrhotite has corroded pyrite in Figure 8 and is thus later in this section. Swanson and Gunning (12) believe that pyrite formed and continued to form during the entire process. Pyrrhotite has formed tabular crystals (Fig. 9), but whether this was selective replacement of muscovite or original crystals some doubt //? exists. Schwartz (9) believes that the crystals have formed as pyrrhotite crystals. In section 6 pyrrhotite appears to have formed earlier than sphalerite. Sphalerite and pyrrhotite show mutual grain boundaries throughout most of the sections indicating contemporaneous deposition. Section 6 shows mutual grain boundaries of sphalerite and chalcopyrite. Figure 6 shows an indication of caries texture suggesting chalcopyrite is later than sphalerite.

Fig. 6 Chalcopyrite and sphalerite
Chalcopyrite - yellow, sphalerite -
purple, pyrrhotite - carmine,
galena - white, gangue - black, X 240.

The texture is not very clear in figure 6, but the overall appearance in the section is suggestive and is offered as a possibility.

Galena forms veins and veinlets through sphalerite and pyrrhotite (Figures 5 and 7). Galena shows selective replacement of sphalerite with respect to galena (Fig. 9).

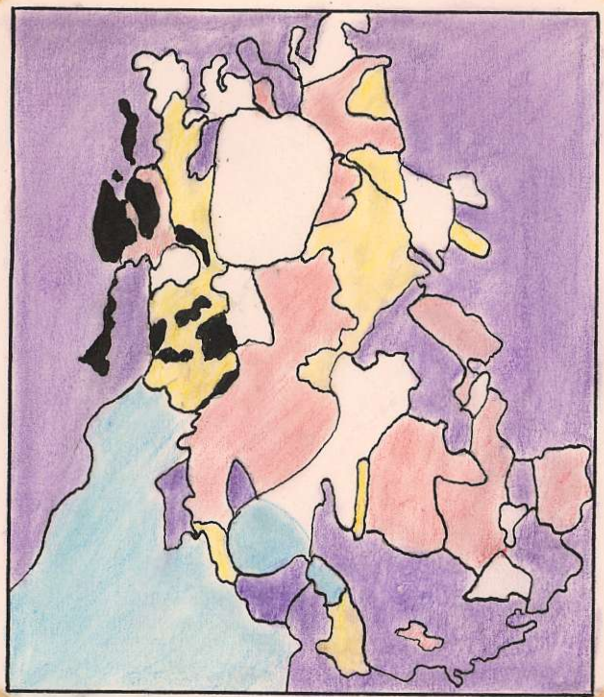

Fig. 7 Vein of boulangerite and galena replacing a lath of pyrrhotite Sphalerite - purple, Chalcopyrite - yellow, pyrrhotite - carmine, galena - white, boulangerite - blue, gangue - black. X 240

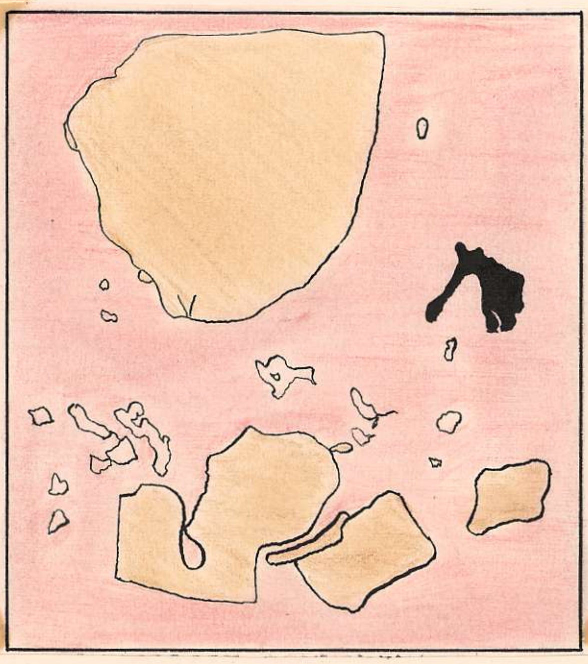

Fig. 8 Pyrrhotite corroding pyrite. X 50

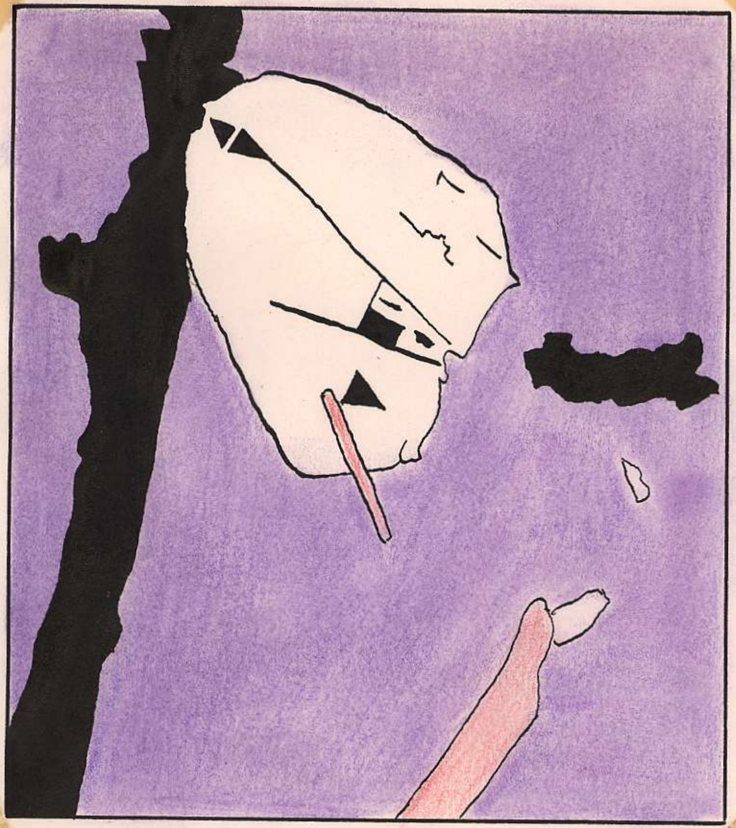

Fig. 9 Galena selectively replacing sphalerite. Galena - white, pyrrhotite - carmine, sphalerite - purple, gangue - black. X 50

Conclusion

Rice (5) has suggested that there was one period of mineralization. Schwartz (9), on the other hand, believes the Sullivan deposit was involved in two distinct periods of mineralization. This would explain the association of high- and low- temperature minerals in the deposit. Swanson and Gunning (12) have the following to say in the matter: "As a concluding comment, we may point out that both the mineralization and the deformation in the Sullivan area shows features that indicate that each of the processes either occupied two distinct periods, or else a single period that was long enough to permit the processes to suffer marked changes in character. The present information does not permit us to choose with certainty between these alternatives."

APPENDIX

The minerals found in the sections were as follows:

Section 1. Galena 25%; sphalerite 55%; pyrrhotite 8%, average grain size 0.4 mm. to massive; boulangerite 7%, average grains size 0.25 mm.; pyrite 2%. average grain size 0.25 mm. arsenopyrite 1%, average grain size 0.27 mm.; chalcopyrite 1%. Figures 4, 7, and 9 illustrate parts of the section.

Section 2. Pyrrhotite 25% average grain size 0.37 mm.; galena 60%; sphalerite 15%, average grain size 0.17 mm.; traces of boulangerite and chalcopyrite. Figure 5 illustrates part of the section.

Section 3. Pyrrhotite 45%, average grain size 0.05 mm.; sphalerite 40%, average grain size 0.05 mm.; galena 15%.

Section 4. Pyrite 50%; sphalerite 30%; chalcopyrite 10%; pyrrhotite 6%; galena 2%; arsenopyrite 2%. Figures 3 and 6 illustrate parts of the section.

Section 5. Pyrrhotite 45%, average grain size 0.16 mm.; galena 35%; sphalerite 20%, average grain size 0.20 mm.

Section 6. Pyrrhotite 83%, massive; sphalerite 12%, average grain size 0.22 mm.; galena 4%, average grain size o.17 mm.; chalcopyrite 1%.

Section 7. Sphalerite 35%, average grain size 0.25 mm.; pyrrhotite 32%, average grain size o.20 mm.; galena 30%; pyrite 3%, average grain size 0.20 mm.

Section 8. Pyrite 50%, average grain size 0.19 mm.; pyrrhotite 23%; galena 10%, average grain size 0.25 mm.; sphalerite 15%; chalcopyrite 2%; arsenopyrite 1%. Figure 8 illustrates part of the section.

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