A very conscientious effort! Should be useful reporting magnesite & rhodochrosite in veins. Apparent lack of inf. on occurrence of Cd in ZnS is surprising?!

15 29/35

A MINERALOGRAPHIC REPORT ON THE HUMMINGBIRD ORES OF THE DUTHIE MINE

DONALD R. WEST

GEOLOGY 409

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The writer also wishes to thank Mr. A.C. Ritchie, of Silver Standard Mines for his suggestions and figures on the metallurgical aspects of this report.

Acknowledgements are also extended to Mr. R. Antoniolli for his information on flotation investigations of the Sil-Van Ores.

FOREWORD

The writer wishes to point out that the property under discussion in this report was previously known as the Duthie Mine. The Duthie Mine, per se, represents one of several properties now held on Hudson Bay Mountain by the Sil-Van Consolidated Mining and Milling Company of Vancouver B.C.

For clarity in operational work this property is generally referred to as the " Duthie " as distinct from other properties in the area. The Hummingbird workings represent an extension of the old Duthie workings and for all practical purposes the geology and mineralogy may be considered essentially similar.

Donald K Wasty

A MINERALOGRAPHIC REPORT ON THE HUMMINGBIRD ORES OF THE DUTHIE MINE

INTRODUCTION

The suite of ores examined in this work was collected by the writer in the course of his employment at the Sil-Van Consolidated Mining and Milling Company's properties during the summer of 1951.

Approximately twenty groups of specimens were collected. With each representative mineral specimen an unaltered specimen of country rock was collected in order that any relationships existing between the ore types and host rock might be noted. Where practicable specimens were taken at 20' intervals along the drift back of the ore zones.

In the compilation of this report the writer strove to ascertain those specific details of mineralogy which would expedite the working out of a flow sheet for the milling of the Hummingbird ores. The specific information sought was:

(1) The occurrence of the gold; the associated metallic minerals and associated gangue; the grain size of the gold; the relationship of the gold to the arsenopyrite.

(2) The occurrence of the silver; the silver bearing minerals; their grain size; their relation to other metallics.

(3) The average and smallest sizes of the lead, silver and zinc minerals.

(4) The extent of the intergrowth between the galena and the sphalerite.

The following procedure was employed in the identification of the ore minerals: polished sections were made by the writer from slabs cut by Mr. J. Donnan of the Geology Department of the University of British Columbia; the minerals were isolated, their physical and optical properties observed and their etch reactions determined. From these data the minerals were either positively identified or grouped with reference to Short's tables.[1] Additional confirmation was obtained through microchemical tests.[2]

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1. M.N. Short, Microscopic Determination of the Ore Minerals, U.S.A. Department of the Interior, Bulletin No. 914, 1940, pp. 105-111.

2. Ibid., pp.173-292.

THE HUMMINGBIRD PROPERTY

LOCATION AND OWNERSHIP

The Hummingbird M.C. adjoins the Canary M.C. on the south slope of Hudson's Bay Mountain about fifteen miles by motor road from Smithers B.C. *which way?*

The Sil-Van consolidated Mining and Milling Co. Ltd owns five groups of mining properties on Hudson's Bay Mountain. They are:

(1) The Duthie

(2) The Canary-Hummingbird

(3)The Mamie

(4) The Coronado-Victory

(5) The Silver Lake, Silver Creek and Homestake.

DEVELOPMENT

The Hummingbird development work was begun in November, 1950, with the cutting of a portal on the 4100' level. To date, about 2000' of drifting has been done along the ore zone and some 700' of ore shoots have been encountered. Two raises, driven to the 4250' level have successfully proved continuity of the ore. Another drift, along the 4250' level, has, at the time of this writing, been advanced about 300' in good ore. The average grade of ore, calculated over a width of 2 feet along the Humminbird 4100' level is given as follows: Gold .16; Silver 15.8 oz/ton and Lead 8.9%, Zinc 11.6%

GENERAL GEOLOGY #

Rhyolites, andesites and altered phases of these volcanic rocks comprise the visible exposures on Hudson's Bay mountain. The Hummingbird property exhibits predominantly silicified rhyolites and andesite breccias. These rocks are part of the Hazelton Group and are believed to be of Middle or Upper Jurassic age.

The Hummingbird ores occur in what may be best described as shear zones. The shear zones are composed of a series of parallel "breaks" in silicified rhyolites and andesite breccias. The minerals occur mainly as fissure fillings within the shears and to a lesser extent as replacing veinlets within the host rocks. The wall rock often constitutes a considerable portion of the ore zones and is found as horses and breccia among the ore minerals. Where included, the wall rock has undergone intensive bleaching, silicification and may show replacement by sulfide stringers.

The shears have an average dip of about 85 degrees to the south-east and strike in a north-easterly direction. At a distance of 900' from the portal the shear zone has been displaced a few feet to the east by a strong fault which dips 55 degrees to the south-east and trends eastwand. Except for minor faulting near the present face the shear zone is very persistent and shows few irregularities throughout its length.

An excellent account of the geology and structure of the Duthie Mine may be found on p.132 et. seq., of the CIMM publication,"Structural Geology of Canadian Ore Deposits"

MINERALOGY - General

The mineralized shear zones vary in width from a few inches to five feet. Where mineralized, the shears contain appreciable amounts of sphalerite, galena, arseno-pyrite, pyrite and minor amounts of pyrrhotite and chalco-pyrite. No silver minerals are seen in place although the sil-ver is known to be present in the approximate ratio of 2 oz. for every 1% of lead (~~Galena~~).

The gangue minerals observed are: quartz, calcite, rhodochrosite and magnesite. Identification by + how ?

In order to present a more complete picture of the mineralogy of this property a brief deseription will be given here of those portions of the ore zones from which the most significant groups of specimens were collected. The assay val-ues corresponding to the precise locale from which the spec-imens were gathered are also given. This precedure may prevent any misconceptions of the relative percentages of the ore min-erals in the polished sections as these sections may be mis-leading in appearance.

The channel samples were taken by the author and assayed by Mr. Doug Willimar of Silver Standard Mines, Ltd. The assay figure are given in the following sequence:

Width Gold Silver Lead Zinc.

The gold and silver are expressed in oz/ton and the lead and zinc as percentages. The widths are in feet.

Specimen No. 1   Sta. 41/8 --0'E

1.9' .06 0.4 8.8 9.8

Sphalerite is found in a strongly brecciated zone in association with galena, pyrite and arsenopyrite. The sphalerite is disseminated finely throughout a siliceous rhyolite. The galena is fine-grained and not macroscopically obvious.

Specimen No. 2   Sta. 41/8 --30' E.

0.5' .02 0.6 Tr. 0.5

This specimen is composed almost entirely of fine-grained arsenopyrite disseminated through siliceous rhyolite. Scattered grains of sphalerite are discernible.

Specimen No. 3   Sta. 41/8-- 60' E.

This specimen is composed of a pinkish-white gangue mineral which exhibits good cleavage and crystal form. It is found in globular crystal masses lining cavities in the sphalerite and as veinlets and inclusions within the ore zone. This specimen has been tentatively identified as rhodochrosite. Check

Specimen No. 7   Sta. 41/10--15' E.

5.0' .16 5.0 2.8 5.4

This specimen is composed of a fairly fine-grained intergrowth of Galena and sphalerite, with sphalerite predominating. Fine-grained arsenopyrite is present on the hanging- and foot-walls and grades into the galena-sphalerite ore toward the middle of the shear zone.

Specimen No. 8   Sta. 41/10--80' E.

1.0' .17 11.3 7.8 1.2

A hi-grade coarse galena with pyrite, sphalerite, chalcopyrite and arsenopyrite, is dominant in this specimen. The hanging-wall carries 1.5' of fine-grained arsenopyrite with minor galena and sphalerite stringers.

<u>Specimen No. 12</u>   Sta. 41/17--30'-60' E.

0.6'   .02   6.1   3.6   4.1

This specimen is representative of a 30' section of ore extending northward from the above station. The mineralization is very regular and consists of fine-grained arsenopyrite intergrowth with sphalerite, galena and pyrite. Quartz and rhodochrosite constitute the gangue. The main shear is open and calcite crystals are fonnd lining the walls.

<u>Specimen No. 14</u>   Sta. 41/16--70' E

1.0'   .23   32.2   15.4   14.2

Coarse, honey-coloured sphalerite is found scattered heavily throughout brecciated wall-rock within the ore zone. The sphalerite is restricted to the hanging-wall and grades to fine-grained arsenopyrite on the foot-wall. A narrow band of good galena extends along the middle of the mineralized zone.

<u>Specimen No.15</u>   Sta. 41/16 --50' E

2.2'   .23   30.2   16.7   16.5

Coarse-grained galena, cleavable sphalerite, and pyrite make up the mineralization of this hi-grade section. The shear zone at this location appears more vein-like than is customary in this deposit. A hanging- and foot-wall are apparent and the sulfides occur in distinct bands.

Specimen No. 16   Sta. 41/16 --20' E.

2.4' .25 6.8 2.1 13.6

This specimen is representative of the highest grade of ore yet encountered. The assay value is somewhat low due to inclusions of waste material. Coarse galena and sphalerite predominate in the hand specimen. The zone is strongly brecciated and large fragments of wall-rock are scattered throughout the ore. Pyrrhotite is unusually abundant in this zone.

Specimen No. 17   Sta. 41/16--30' E

3.5' .18 25.3 12.2 20.1

The mineralization of this zone is of very high grade similar to No. 16. This particular specimen, however, is particularly high in clean galena and it was hoped that the silver values might be run down in sections made from this ore. Pyrite is in close association with high galena content throughout this zone.

MINERALOGY - Detailed

In addition to those polished sections made by the writer, all sections made by previous writers were re-examined in order to correlate the Hummingbird ores with the ores from the lower (Duthie) levels of the mine.[3] Those polished sections described by the writer refer only to the Hummingbird ores and for purposes of reference bear the same number as do the specimens described above.

3. W.J. Clarke, A Microscopic Examination of the Ores of the Duthie Mine, Geology 409 Report, University of British Columbia, 19--?
A.K. Roberts, The Mineralogy of the Ores of the Duthie Mine, Smithers, B.C., Geology 409 Report, University of British Columbia, April 1948.

Pyrite:

Pyrite was probably the first mineral to be deposited. It is the most extensively brecciated mineral and is found to be replaced by all other minerals. Pyrite occurs as massive, anhedral grains of variable size. The fracture pattern of the pyrite affords good evidence of the early deposition of this mineral since the fractures do not extend into the niezhboring brittle minerals (Fig. 3). Pyrite is abundant in the higher grade ores, (Sect's 12,16) but occurs as a minor constituent in the lower grade ores.

Pyrite is a notably non-stoichiometric mineral and the possibility of its carrying gold should not be ignored. No gold could be found in association with the pyrite although a diligent search was carried out using the oil-immersion lens.

Arsenopyrite:

This mineral is found in all sections and is the dominant sulfide mineral in the ore. It occurs as euhedral crystals varying from microscopic to 5mm. in size and as massive , irregular bodies of indeterminate size. Arsenopyrite apparently was one of the earlier-formed minerals since it is replaced by nearly all sulfides and is found replacing quartz and pyrite. Considerable attention was devoted to exploring the possibility of an occurrence of gold with the arsenopyrite. A specimen exhibiting a high polish was examined with the aid of the oil immersion lens but no gold was discovered.

Pyrrhotite:

Pyrrhotite is present in two occurrences and two periods of deposition are evident. The first deposition, one of higher temperature, occurred early in the history of the mineral deposit. Here pyrrhotite is found veining and replacing hypogene carbonate and cementing fragments of pyrite. All subsequently deposited minerals are found replacing pyrrhotite. Rounded residuals of pyrrhotite are a common occurrence throughout other sulfides (fig. 15).

In its second occurrence pyrrhotite is found as an ex-solution mineral in sphalerite. It occurs as elongate blebs along the crystallographic planes of the sphalerite and as rounded blebs at the grain boundaries of the sphalerite. The ex-solution bodies range in size from 10-100 microns with an average size of about 25 microns. The residuals of pyrrhotite range in size up to 300 microns.

Sphalerite:

Sphalerite is the predominant ore mineral and occurs at an average grade of about 12 % throughout the ore body. It replaces quartz, arsenopyrite and carbonate extensively. (Fig. 1, 2, 16)

In the higher grade ore zones, as represented by the sections 14,15,16 and 17 the sphalerite is closely associated with the galena. These minerals bear smooth, curved boundary relations to each other and very little intergrowth is present.

Since the sphalerite is being replaced by the galena, occasional isolated, rounded grains of sphalerite are found within the galena and to a lesser extent similar forms of galena may be found within the sphalerite.

Due to the irregular grain sizes and continuity involved in the sphalerite-galena ore it is difficult to arrive at an average grain size for these minerals. However, it may suffice to say that the mutual boundary relations of these two minerals show practically no intergrowth, the minerals are of coarse grain and their separation by grinding and flotation should be highly efficient.

In the ore zone extending eastward from the vicinity of Sta. 41/17 the mineralization is of a much finer grain and the sphalerite is found to be intimately intergrown with quartz, arsenopyrite and some galena. (Fig. 1,2,4,16). Again, due to the continuous nature of the ore minerals which here show a banded texture, grain sizes were indeterminable. It is probable that ore milled from this zone will not show as efficient a separation as will the coarser, higher grade zones.

The sphalerite ranges in colour from a yellow-brown in the high grade ores to a dark brown in the lower grade, fine-grained ores. The colour of the sphalerite is a criterion of its own content.[4]

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4. A.B. EDWARDS, TEXTURES OF THE ORE MINERALS, Australian Institute of Mining and Metallurgy, Melbourne, 1947, p.68.

Iron is known to be contained in sphalerite to the amount of 17%. The yellow-coloured sphalerite may contain up to 4% Fe, the darker brown variety up to 10% Fe and black, highly lustrous sphalerite (Marmatite) may contain up to 17% Fe. The average grade of sphalerite here is of the dark brown variety and will probably range from 5-10% Fe.

Chalcopyrite:

Chalcopyrite is a common mineral in most sections although it probably constitutes less than 1% of the ore.

Chalcopyrite probably had two periods of deposition although the evidence for this is not conclusive. In one occurrence, chalcopyrite is found as ex-solution bodies along twinning planes of sphalerite and as grains of irregular size scattered throughout the sphalerite. (Fig. 8). Chalcopyrite is also seen as veinlets with matched borders, cutting but not extending past the sphalerite. The above occurrences suggest contemporaneous deposition of sphalerite-chalcopyrite.

In its second occurrence chalcopyrite shows strong selective replacement of hypogene carbonate in preference to existing sulfides. (Fig. 7). Of the sulfide minerals, pyrrhotite is most strongly replaced and an intimate association of chalcopyrite, carbonate and pyrrhotite is common to Sections 14, 17.

Only minor occurrences of chalcopyrite are noted in association with galena and tetrahedrite. The smooth, curved, "mutual boundaries" relationships observed here suggest contemproaneous deposition and ex-solution to the grain boundaries of the galena and tetrahedrite (Fig. 15).

Marcasite:

Marcasite in hypogene ores is often diagnostic of the former presence of pyrrhotite.[5] This statement seems to be borne out by the occurrence of marcasite in this ore as characteristic composite lamallae which suggest the former presence of pyrrhotite, (Fig.6). The texture and strong anisotropism of the mineral distinguish it from pyrite with which it is in close contact in some sections.

Galena:

Galena occurs throughout the ore bodies at an average grade of about 8%. ~~Although~~ Galena is the most important ore mineral since it carries nearly all of the gold-silver values. Galena is found replacing all sulfides of earlier deposition with sphalerite in particular being strongly replaced. Sphalerite-galena boundary relations exhibit the characteristic "reversed caries" texture. (Fig 4,6).

Examination of the assay values of the mine samples shows a very regular relationship existing between the lead content and the silver content of this ore. It may be seen that for each 1% of Pb in the ore, approximately 2 oz. of Ag are present. (pp. 6-8). Galena is capable of centaining a

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5. Edwards, op. cit. p.100

maximum of about 30 oz of silver per ton in solid solution, but when silver is present in excess of this amount the galena invariably contains silver minerals.[6]

Since this ore carries (Pb) value greatly in excess of 30 oz/ton it may be concluded that while some solid solution silver may be present, the greater part of the silver values are carried as another mineral within the galena.

Tetrahedrite:

Tetrahedrite was found only in the galena. Here it has exsolved along crystallographic planes as minute needle- and rod-like forms averaging about 20 microns in length and 3 to 4 microns in width.

Tetrahedrite is also found as horn-like protuberances, attached to sphalerite grains and concentrated at or near the sphalerite-galena contacts and may occasionally be found attached to other sulfide grains within the galena. (Fig. 13). These occurrences range in size up to 200 microns and average about 50 microns.

The grain sizes of the tetrahedrite prohibited the obtaining of a "clean" specimen for X-ray analysis of silver content. A microchemical test, made from tetrahedrite-rich galena yielded silver bichromate crystals. There was, however, the possibility of contamination by other silver bearing minerals.

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6. H. V. Warren, "Distribution of Silver in Base Metal Ores," Trans. Amer. Inst. Min. Met. Eng., Vol. 115, 1935, pp. 81-88.

As tetrahedrite is the only mineral occurring in significant amounts in the galena, and since it is extremely regular in its association with the galena, it is conceivable that the tetrahedrite might be of the argentiferous variety, known as Freibergite. The regular occurrence of the tetrahedrite would be synonymous with the regular silver values.

Native Silver:

Native silver is confined almost entirely to the galena, where it occurs as rounded grains varying in size from 2 microns to a maximum of 200microns with an average size of about 30 microns. Native silver is distinguished by its white colour against galena and by etch reactions. Silver can only be found in relatively "pure" galena from the high grade zones. It is irregular in occurrence and difficult to observe. About twenty grains were observed in all. The irregular and sparse occurrence of this mineral do not suggest it to be the main source of the silver values. The rounded "mutual boundaries" relationship of the native silver to the galena suggest it to be of hypogene (primary) origin. One grain of silver, 200 microns in diameter was found associated with sphalerite (Fig. 16).

Electrum:

Electrum was found within galena only and in similar occurence to native silver. The grain sizes of the electrum never exceeded 90 microns and averaged about 30 - 40 microns in diameter. The relative gold-silver content of the electrum could be estimated roughly by observing the colour of the mineral. Some electrum possessed a deep yellow colour and was probably of high gold content. Most electrum was of a pale yellow colour and about ten occurrences were noted, all in relatively "pure" galena.

Gold:

Native gold was not positively identified, although some electrum was of a pronounced gold colour. A mineral suspected of being gold was found on two occassions within grains of electrum. (Fig. 18). This is not a normal occurrence since silver and gold are completely miscible in electrum and this mineral is therefore classed as unknown. Check

Dyscrasite? Ag_3Sb

This mineral was discovered in a grain of silver-rich electrum of pale yellow colour andabout 70 microns in diameter. The mineral was visible under plain light as a faint shadow-like structure within the electrum.

An etch with dilute $FeCl_3$ tarnished the electrum irridescent and stained the dyscrasite dark brown. Normally, electrum is negative to $FeCl_3$, but native silver would tarnish irridescent. However, this mineral (electrum) had a definite yellow colour which suggests that it was not native silver, but probably a silver-rich electrum.

When etched, the dyscrasite stood out in a characteristic grating structure (Fig. 19). Although this occurrence was of prohibitive size for michrochemical or X-ray identification, its etch reaction andcharacteristic structure suggest dyscrasite.

Dyscrasite usually exists as a solid solution of silver and antimony and occurs as exsolution lamellae within antimonial silver.

Ruby Silver - Pyrargyrite:

No pyrargyrite was discovered in the Hummingbird ores. The pyrargyrite described here was found as visible mineralin hand picked specimens taken by the writer from old stopes on the Mill and Compressor levels of the Duthie mine. The purpose in taking these specimens was to decide the controversial point of whether or not the ruby silver is primary.

In the polished sections no evidence was found to suggest that the pyrargyrite is not primary. No secondary replacement textures are visible. The pyrargyrite occurs as large masses showing smooth, curved boundary relations with the galena (Fig. 9, 10) and as veinlets with matched borders along galena cleavage planes (Fig. 17). The pyrargyrite is a typically late silver mineral in the formation of an ore deposit and is usually restricted to the upper levels of the mine[7]

7. Irving and Bancroft "Geology of Ore Deposits near Lake City, Col." Bull. U.S.G.S., No. 478, Washington, 1911, p. 63.

Ransome holds that ruby silvers are characteristic of downward sulfide enrichment.[8] There is no evidence of supergene enrichment or the formation of secondary metallic minerals in this deposit.

Most writers suggest that ruby silver may be primary or secondary. In this deposit the pyrargyrite, from examination of its relationships with the galena, would appear to be primary. The control of the pyrargyrite deposition is likely one of temperature and since the Hummingbird development shows an association of higher temperature minerals than do the lower workings, it is unlikely that pyrargyrite will be found on the upper levels.

Greenockite? (CdS)

This mineral was not seen in the polished sections. An assay of "pure" sphalerite by Sil-Van Mines Ltd. disclosed the presence of cadmium in the amount of .39% per ton.

Cadmium is generally found as the cadmium sulfide, greenockite and occurs as coating on the sphalerite grains. It is probable that greenockite is the cadmium bearing mineral in this occurrence. Never heard of it in ZnS ?

8. "Criteria of Downward Sulfide Enrichment", Ecom. Geol., Vol. 5, 1910, p. 211.

PARAGENESIS

The metallic minerals determined in this investigation are given here in their approximate order of deposition:

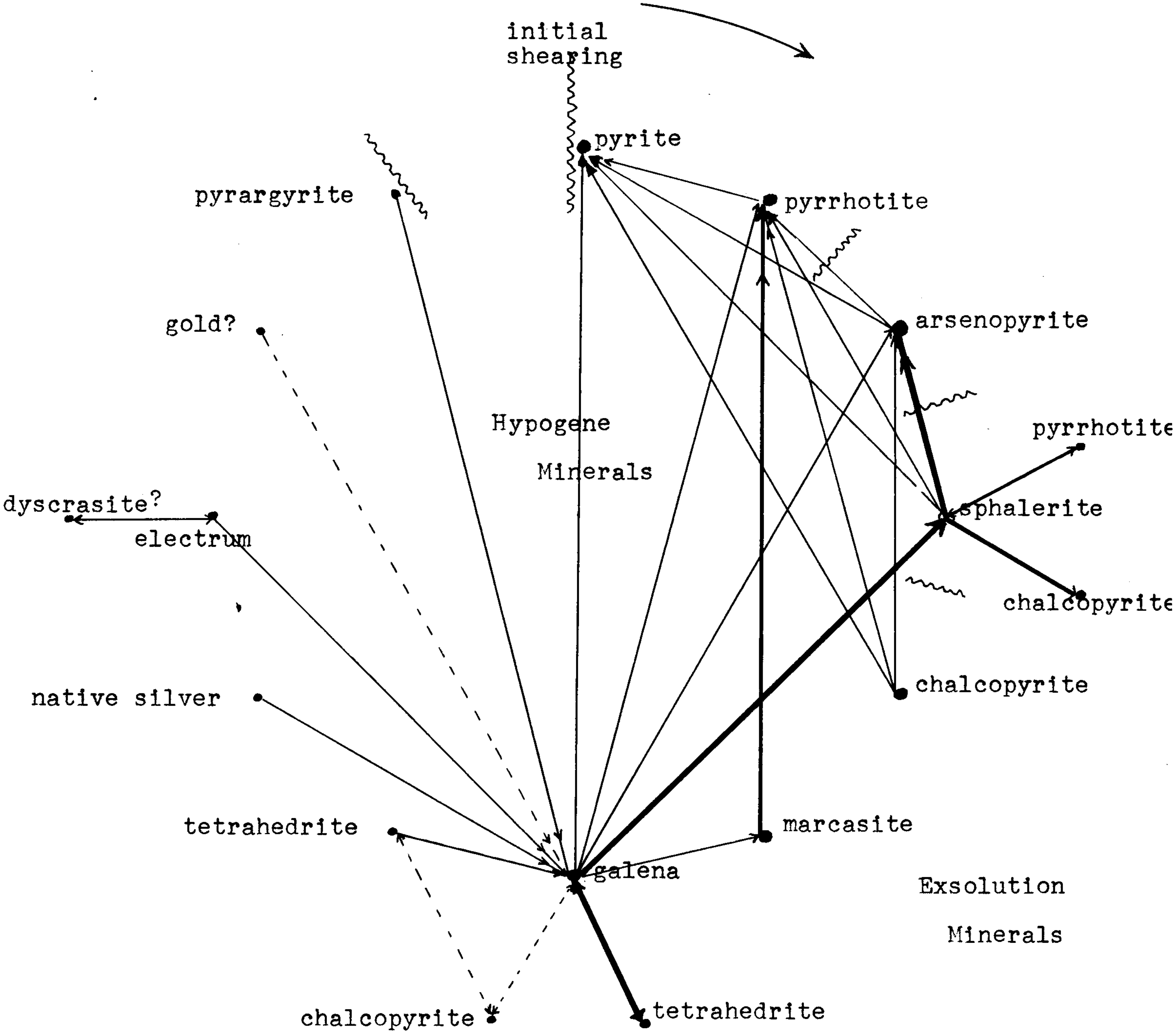
Pyrite	FeS
Pyrrhotite	$Fe_{(1-x)}S$
Arsenopyrite	$FeAsS$
Sphalerite	ZnS
Chalcopyrite	$CuFeS_2$
Marcasite	FeS
Galena	PbS
Tetrahedrite	$(Cu,Fe)_{12}\cdot Sb_4S_{13}$
Silver	Ag
Electrum	(Ag,Au)
Gold?	Au
Dyscrasite?	Ag_3Sb
Pyrargyrite	$3Ag_2S\cdot Sb_2S_3$
Greenockite?	CdS

Paragenetic Diagram. - Abstract.

The ore minerals are arranged on the circumference of a circle and are represented by points. Lines connect each pair of minerals which are observed to be in contact. An arrow head points toward the mineral replaced where replacement textures are represented. The absence of an arrow indicates simultaneous deposition. The minerals formed by exsolution are attached to the primary mineral by a line to the exsolution mineral point which is putside the hypogene ore mineral circle.The density of the connecting lines in the diagram indicates semi-quantitatively the relative replaceability of the host minerals.

The sequence of deposition follows clockwise from the top of the diagram.Minor or inconclusive relations are indicated dy dashed lines.

PARAGENETIC DIAGRAM OF METALLIC MINERALS#



after Forbes Robertson and Paul L. Vandeveer, Economic Geology, Vol. 47 No. 1, 1952.

Paragenesis - Discussion:

The evidence gathered from the examination of thin sections of rock and polished mineral sections indicate that the first stage of mineralization of this deposit, following the initial stresses which formed the shear zones, was ore of intense carbonatization and replacement of wall-rock by hypogene carbonates.

The examination of the polished sections suggests that pyrite was the first sulfide to be deposited; it is the most heavily brecciated mineral and shows replacement by nearly all subsequent sulfides.

The deposition of the pyrite was followed by a shearing which fractured the pyrite and introduced hypogene carbonate and pyrrhotite. The fracture patterns in this deposit afford good evidence of mineral succession. Where a set of fractures cut one group of minerals and abutt against another, it may be taken as evidence that the fractured mineral is the older. Consideration must be given in this respect to the relative brittleness of the minerals concerned. Three distinct sets of fractures were observed in this examination and are believed to represent three periods of shearing and subsequent deposition of new minerals.

Pyrrhotite is found replacing hypogene carbonate selectively and cementing brecciated fragments of pyrite. Where pyrrhotite veins pyrite distinctly corroded margins of the pyrite are evidenced.

A second set of fractures which cuts pyrrhotite, carbonate and pyrite simultaneously is taken as evidence of shearing subsequent to the pyrrhotite-carbonate deposition.

Quartz and arsenopyrite were then deposited in what appears to be an overlapping period of deposition. In general, the arsenopyrite crystals are found growing within quartz, but may also be corroded by the quartz. (Fig. 1,2,). Time and temperature conditions permitted the quartz andarsenopyrite to develop euhedral crystals throughout most of the deposit.(Fig. 5)

Sphalerite was the first ore mineral to be deposited and is found replacing all earlier minerals. Exsolution pyrrhotite and chalcopyrite accompanied the deposition of the sphalerite.

Another generation of quartz and carbonate followed the deposition of the sphalerite, since the latter is brecciated and veined by these minerals and earlier quartz crystals are cemented by massive quartz. The deposition of quartz-carbonate here would conform to the conditions of temperature and acidity change necessary for the alteration of pyrrhotite to marcasite as observed in Fig. 6. The relationships of the marcasite to the other minerals suggests that it was of earlier deposition than the ore minerals. If the marcasite were replacing pyrrhotite as is suspected, the marcasite would appear to be older than the ore minerals since it would conform to the original shape of the pyrrhotite.

Galena was the next mineral to be deposited and replaces most minerals and especially sphalerite. The galena-sphalerite boundaries have "reversed caries" texture which suggest that the sphalerite is later. This effect, however, is typical of these two minerals and may occur whenever the host mineral has a tendency to form rounded grains. Tetrahedrite accompanied the galena deposition and is found as exsolution forms within the galena. Minor chalcopyrite appears to have been deposited contemporaneously with the galena and usually has exsolved to the grain borders.

The electrum, native silver, gold? and dyscrasite? are evidently of hypogene origin and their deposition probably occurred with or subsequent to the deposition of the galena.

Movement along the fault zone has opened a continuous shear which may be traced for most of the length of the ore body. Supergene filling of this fissure by calcite and chalcedony has produced a typical encrusted deposit of mineralogical interest.

Post-mineralization faulting has resulted in minor displacements of the ore and may have been responsible for developing curved cleavage traces in some of the galena specimens,indicating stress of the galena and subsequent deformation by bending rather than fracturing.

Paragenetic Summary:

1. The minerals were deposited in at least four periods of deposition and have suffered post-mineralization stresses.

2. Gold and silver are present as free grains within the galena.

3. The gold bears no apparent relation to the iron minerals.

4. No supergene enrichment has occurred in this deposit; ruby silver of the lower levels is believed to be hypogene.

5. The main silver values are probably present as argentiferous tetrahedrite within the galena.

6. The intergrowth between the sphalerite and galena is minimal.

7. The mineralogy varies considerably within the ore body.

Paragenetic Conclusions:

The mineralogy of the Hummingbird ores appears to be fairly simple; a minimum of intergrowth of the lead-zinc mineralization should produce efficient recovery of these minerals. The silver and gold should occur in the lead concentrate as is desirable.

A loss of gold and silver in the tailings may be caused by overgrinding. Grinding at about 200 mesh, or 70 microns would not normally free the silver or gold minerals since their average size is less than 70 microns. However, other metallurgical factors, with which the writer is not cognizant may enter the picture.

Any silver losses in the zinc concentrates may be the result of occasional grains of native silver within, or grains of tetrahedrite attached to, the sphalerite. The colour of the sphalerite suggest an undesirable content of iron. This factor is compensated for by the presence of cadmium with the sphalerite.

Examination of polished sections from the lower mine workings indicates a progressive upward change in mineralogy. The Hummingbird ores are suggestive of higher temperature conditions. The sections from the Mill and Compressor levels show ruby silver, a greatly increased tetrahedrite content, considerable chalcopyrite in the galena, a greater percentage of galena over sphalerite and a much greater intergrowth of the latter.

The following table shows the expected metal recoveries of the Hummingbird ores and their comparison with results obtained with the Duthie ores during previous operations.#

The Hummingbird figures were supplied by Mr. A.C. Ritchie of the Silver Standard Mines and the Duthie figures were taken from the milling records of Duthie Mines Ltd.

	Duthie	Hummingbird
Pb Concentrate		
	Pb 62%	Pb 70%
	Ag 430 oz.	Ag 150 oz. (est)
	Zn 6.5%	Zn 4%
Zn Concentrate		
	Zn 51%	Zn 50%
	Ag 35 oz.	Ag 5-6 oz.
	Pb 1%	Pb 1%
Metal recovery from Ore		
	Pb 95%	Pb 95%
	Ag 94%	Ag 85%
	Zn 70 - 80%	Zn 92%

From these figures it may be seen that the respective results are comparable except for the silver values. In the Duthie, ruby silver accounts for the higher silver values in the Pb and Zn concentrates. Pb recovery is higher in the Hummingbird, probably as a result of a less extensive intergrowth of Pb - Zn. This is further evidenced by lower Zn values in the Pb concentrate.

In overall metal recovery from the ores the Duthie shows higher Ag. recovery and comparable Pb recovery. The Duthie Zn recovery is considerably lower than that of the Hummingbird. This may be due in part to the extensive intergrowth of Pb - Zn and increased Zn in the Pb concentrate.

The recovery of Zn in the Duthie ores was found to be dependent upon its freedom from pyrite and the recovery was in variance with the pyrite content of the ores.

The overall mineralogy of this deposit suggests it to be one of intermediate temperature (mesothermal) with a gradation upwards to higher temperature conditions. The ore minerals were probably deposited at temperatures between 250 and 500 degrees Centigrade. The hypogene character of the ore suggests that barring structural cut - offs, the ore should persist to depth.

Suggestions for further work:

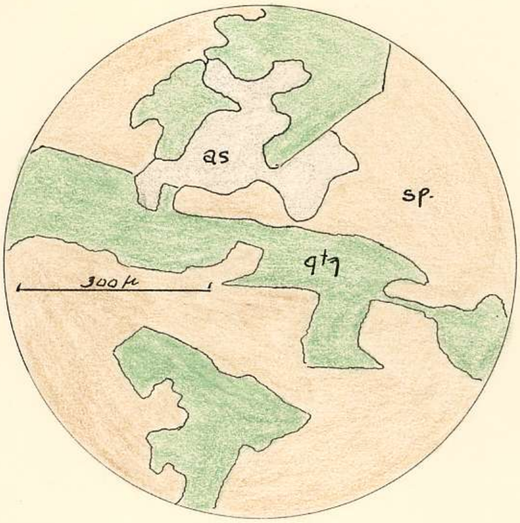
1. Products from each stage of milling should be taken and examined microscopically if losses of metals due to milling are encountered.

2. Superpanning of the ores to obtain fractions for microscopic examination should be done if precious metal values are found to persist in the tailings.

3. An X-Ray analysis of a clean fragment of tetrahedrite, if obtainable, would verify the presence of silver in this mineral.

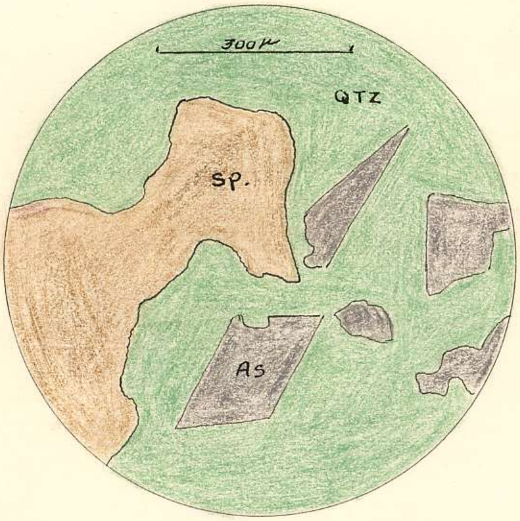
4. Further work, of mineralogical interest might be done on the Dyscrasite? and unknown mineral found to occur with the electrum.

Fig. 1



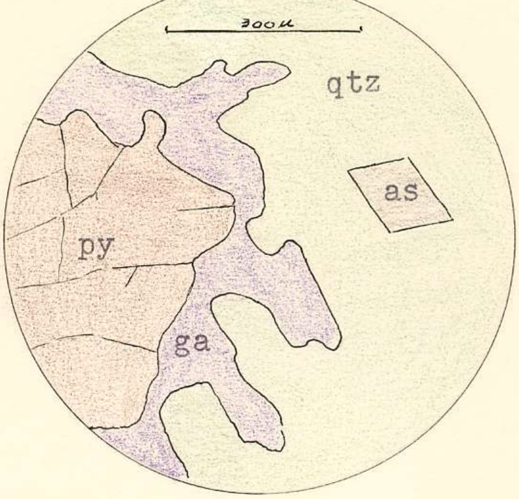
A typical intergrowth of sphalerite, arsenopyrite and quartz is shown here. This is characteristic of the finer grained, lower grade of ore.

Fig. 2



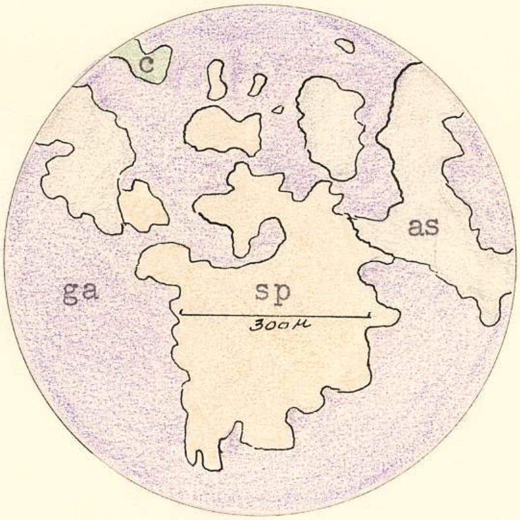
A similar occurrence to Fig 1 is indicated. This figure suggests simultaneous deposition of quartz and arsenopyrite since the arsenopyrite crystals have apparently grown in the quartz but also show corrosion by the latter,

Fig. 3



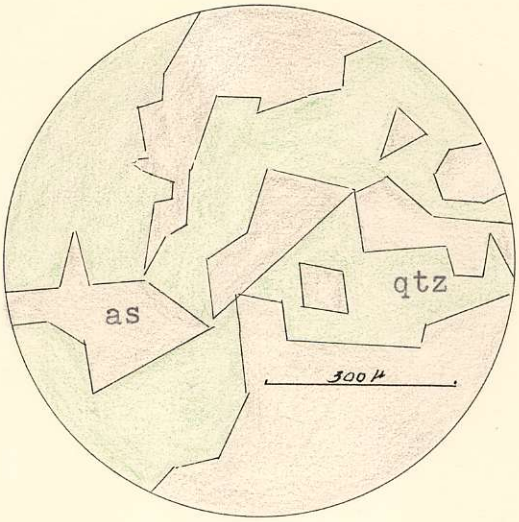
Galena is shown replacing brecciated pyrite and massive quartz. A euhedral crystal of arsenopyrite is shown lying within the quartz.

Fig. 4



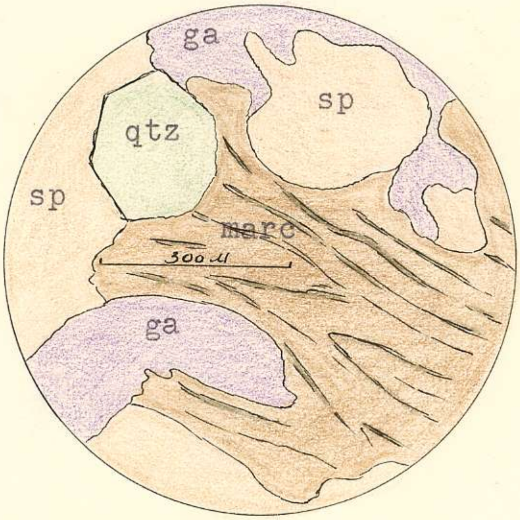
Galena is shown replacing extensively sphalerite, arsenopyrite and hypogene carbonate. This figure represents a more extensive intergrowth than is common to the higher grade of ore

Fig. 5



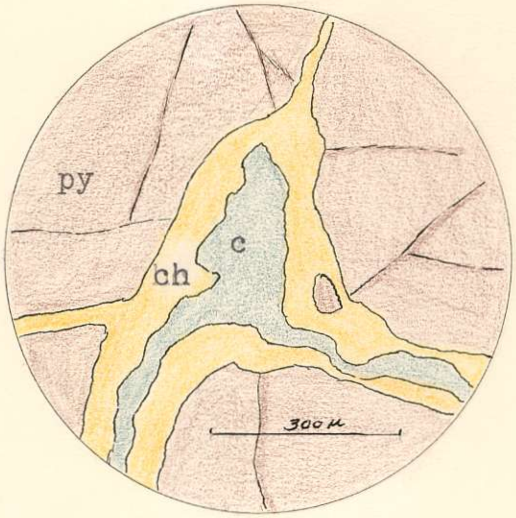
Euhedral to subhedral crystals of arsenopyrite are shown growing in quartz. This mineralization is typical of the lower grade high arsenopyrite ores of this deposit.

Fig. 6



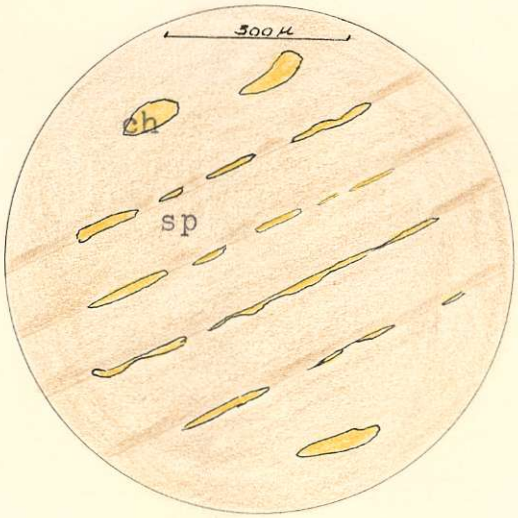
Marcasite in characteristic composite lamellae is indicated and shows replacement by galena. The Marcasite here is beleived to have resulted from the alteration of pyrrhotite.

Fig. 7



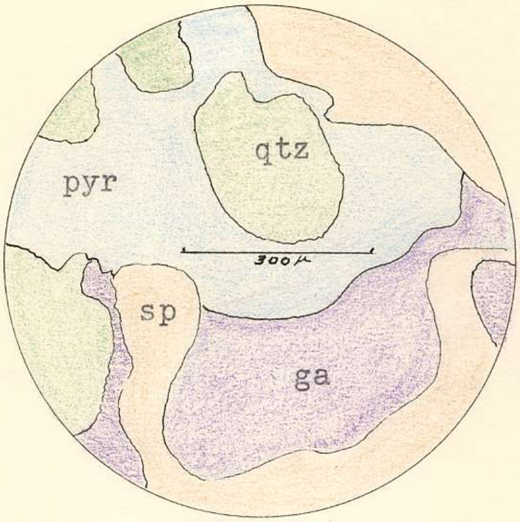
Chalcopyrite is shown replacing hypogene carbonate which had originally veined brecciated pyrite.

Fig. 8



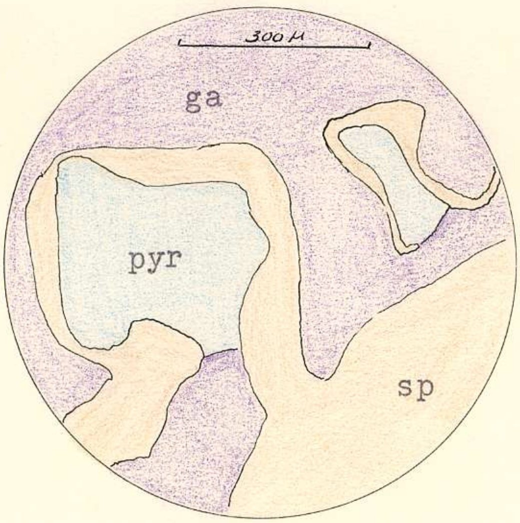
Chalcopyrite is shown as exsolution bodies along the (111) twin planes of sphalerite

Fig 9



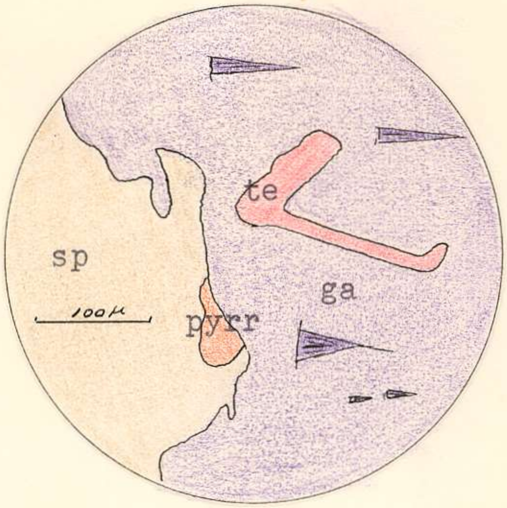
Pyrargyrite from the Compressor Level is seen in typical occurrence within galena. This occurrence suggests the pyrargyrite to be of primary origin.

Fig 10



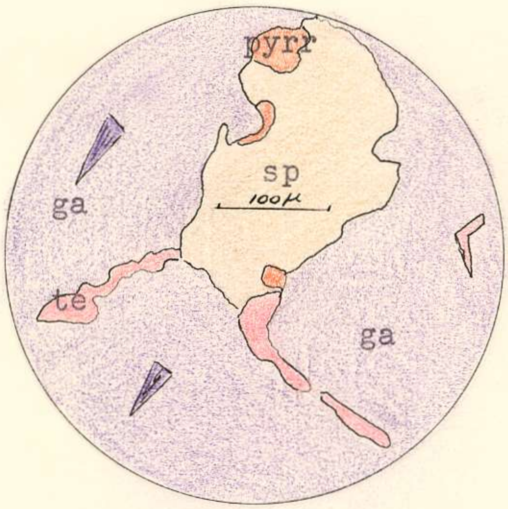
Pyrargyrite is seen replacing galena which has replaced sphalerite. The replacement has begun from the core of the sphalerite and has left residual rims of sphalerite throughout the galena.

Fig. 11



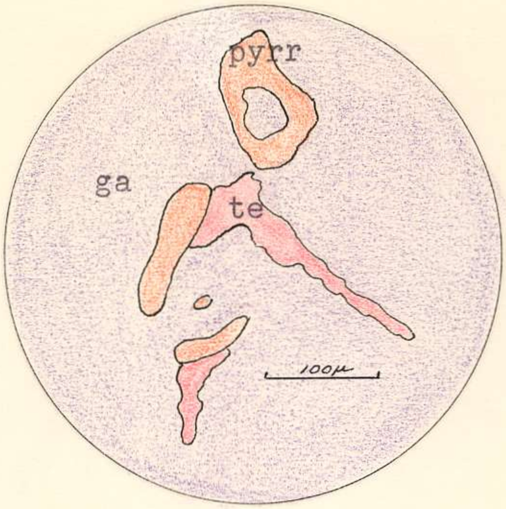
A characteristic bleb of tetrahedrite is seen conforming generally to cleavage of galena in the usual position near the sphalerite-galena boundary. A bleb of pyrrhotite has exsolved to the grain boundary of the sphalerite.

Fig. 12



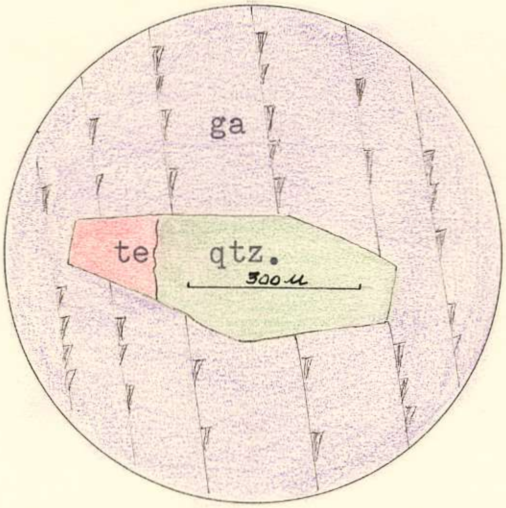
This figure indicates the tendency of tetrahedrite to exsolve to the boundaries of the galena and to become attached to sphalerite grains. Pyrrhotite is in evidence within the sphalerite as the usual exsolution blebs.

Fig. 13



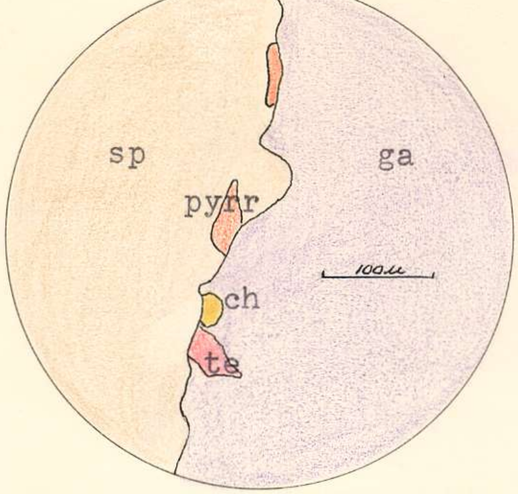
Tetrahedrite is shown attached to residual blebs of pyrrhotite which have been partially replaced by the galena.

Fig. 14



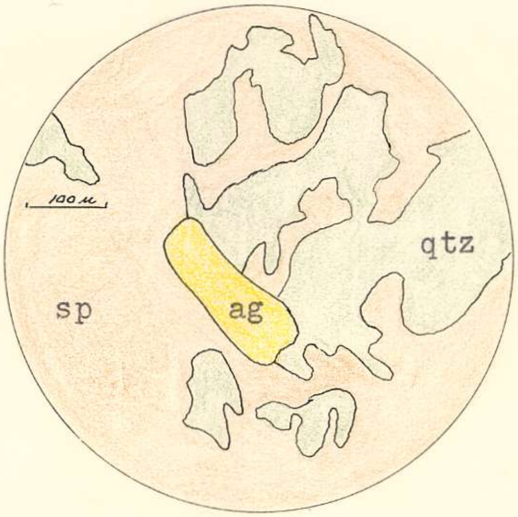
Tetrahedrite appears to be pseudomorphous after quartz. The continuous cleavage traces of the galena on either side of the quartz crystal suggest that the quartz crystal was later than the galena. This was an isolated occurrence .

F Fig. 15



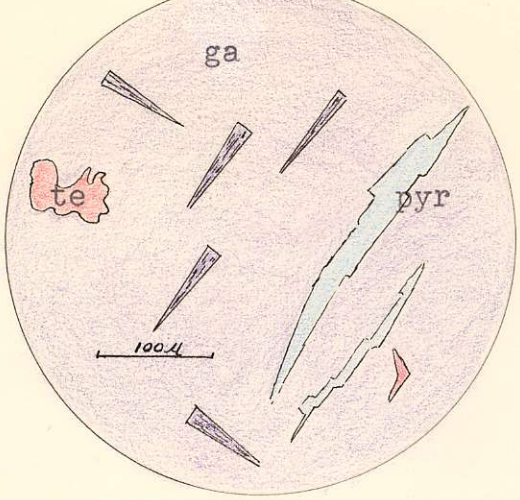
Exsolution blebs of pyrrhotite areseen at the sphalerite borders while exsolution blebs of tetrahedrite and chalcopyrite are seen at the galena border. The smooth, curved boundary betwoen the sphalerite and galena is typified here.

Fig. 16



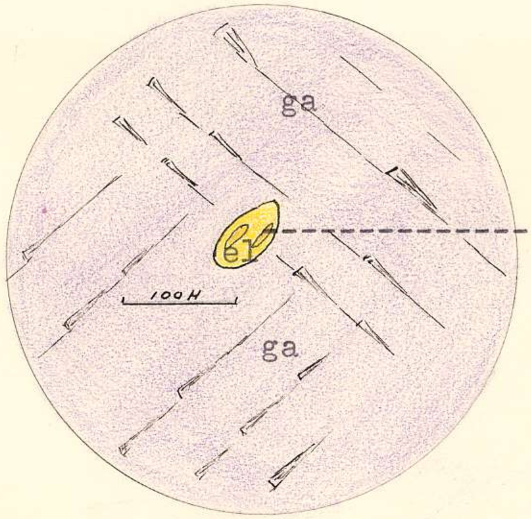
The only occurrence of native silver outside galena is shown here. The grain was the largest one discovered in this investigation.

Fig. 17



Ruby silver from the Mill Level is found as veinlets with matched borders following cleavage cracks in galena. Tetrahedrite is found closely associated with the ruby silver in ores from this level.

Fig. 18



This figure represents one of two occurrences found where a grain of electrum contained smaller grains within which were of a deeper yellow color than the electrum. Native gold was suggested but would indicate an unusual association since gold and silver are completely miscible in electrum.

Dyscrasite? (Ag_3Sb)

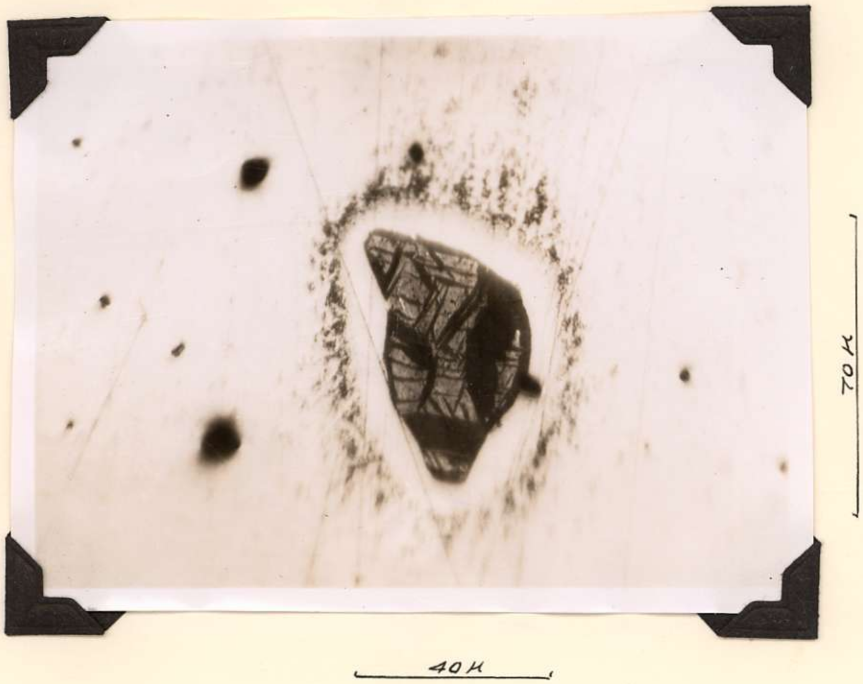


Fig. 19

Dyscrasite? (black) is seen as agrating structure within a grain of silver-rich electrum. The ground mass is galena. The specimen is etched with dilute $FeCl_3$ and has a residual halo which would not wash off.

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