

*a careful, conscientious effort*

$\frac{31}{35}$

A MINERALOGRAPHIC INSPECTION  
OF THE MAMIE ORE (SMITHERS, B. C.)

600303

ROBERTO ANTONIOLLI

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The University of British Columbia  
Vancouver, CANADA.

University of British Columbia,  
Vancouver, B. C.

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Dr. H. V. Warren,  
University of British Columbia,  
Vancouver, British Columbia.

Sir:

I have the honour to submit this essay as partial fulfilment of the requirements for Geology 409.

Since the time of my employment in the laboratory of the Silver Standard Mines Ltd., I have been impressed by the role of mineralographic investigations in metallurgy. I wish to thank you for having allowed me to choose for the present work the Mamie ore, in the flotation of which I am being directly interested.

In this report I have constantly emphasized those points that are in closer connection with flotation processes.

Yours very truly,

*Roberto Antonioli*

Roberto Antonioli

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## ACKNOWLEDGMENT

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## PURPOSE

The present work has been carried on in connection with flotation tests conducted on the same Mamie ore. Its original purpose was to investigate the occurrence of silver and gold, and consequently determine the nature of the precious metal losses taking place in the metallurgical tests. The work has failed in this purpose, since neither the precious metals nor their minerals could be recognized. However, some of the limitations to be expected from flotation processes, as applied to this ore, have been established.

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A MINERALOGRAPHIC INSPECTION  
OF THE MAMIE ORE (SMITHERS, B. C.)

Location and history of the Mamie mine

The mineral property is situated on the southern slope of the Hudson Bay Mountain, in the Omineca Mining Division, and belongs to the Sil-Van Consolidated Mining and Milling Co.

This company has been recently formed, but mining in the district started in 1922 and was carried on in the so-called Henderson zone, on account of the Duthie Mine.

From the Duthie Mine some sorted lead-zinc ore was shipped from 1922 to 1927. In 1927 a flotation mill was built, which operated to 1930. From 1930 to 1942 the mine was worked by lessees. In 1946-47 diamond drilling and 450 ft. of drifting were carried out on an extension of the

Henderson zone. Results were encouraging but inconclusive.

The Sil-Van Consolidated Mining and Milling Co. was founded in 1950 to acquire 71 claims on the southern slope of the Hudson Bay Mountain. It includes: the old Duthie Mine, on the Henderson, Canary and Hummingbird claims; the Mamie, Victory, Coronado, Homestake, Silver Lake and Silver Creek, groups of claims.

The base of operation is the Duthie Camp, situated 15 miles from Smithers by good road. A 150-ton flotation mill for the treatment of the Sil-Van ore is going to be operating before the end of 1952.

### Geology<sup>1</sup>

"The Hudson Bay Mountain has been an outstanding center of prospecting and mining for many years. There are probably at least one hundred known deposits that contain one or more of the following metals in important quantities: gold, silver, lead, zinc and copper.

"Around the outer part of the main mountain there are three areas of Lower Cretaceous or Skeena sediments.

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1 From "Mineral Resources, Prince Rupert to Prince George, B. C." by F. A. Kerr, 1936; as condensed by Heward G. Little

Erosion has removed most of them and has cut into the core, which as now exposed is made up mainly of massive volcanic rocks (of Jurassic or Hazelton age). In the center of these there is believed to be an inner granitic core, represented at the surface by small stocks on the northern peak and at other places by dykes.

"It is believed that the granitic rock in the center was intruded under great force and caused doming of the rocks, as well as minor deformations, much fracturing, induration, and alteration. After granitic rock had started to solidify, but before much cooling had set in, mineralizing solutions were given off and tended to seek out fractures, shear zones, and bedding planes. Mineralization continued over a considerable period of time and changed in character so that at different times different minerals were deposited.

"Similarities in the character of the mineral deposits seem to show that all were formed by mineralizing solutions from the same magmatic source."

"The country rock of the Mamie mine consists of andesitic flows and breccias, varying in color from dark grey to purple. The breccias frequently are green, due to the presence of epidote, which is secondary after hornblende.



"A sheared and brecciated zone strikes north 70 degrees east and dips steeply southeast. Mineralization occurs in this shear zone. The Mamie vein belongs to the same system as the Duthie (Henderson), Coronado and Victory veins, which all have a northeast trend."

The Mamie ore may be defined essentially as a zinc ore with conspicuous amounts of silver, gold, copper and lead.

#### Mineralographic inspection

This is the second microscopic investigation of the Mamie ore; the first was carried out by Mr. H. G. Little in 1936. The present suite of specimens, however, comes from new exploration and development workings and the conclusions reached in the two reports are not necessarily expected to coincide.

The nine specimens examined by the writer were part of a sample shipped from the Mamie mine in November 1951 for metallurgical testing. They were so picked as to be representative of the mineralization of the original sample. See list of specimens in Appendix I.

#### Minerals.

The minerals identified are: arsenopyrite, pyrrhotite, dark sphalerite (marmatite), chalcopyrite, marcasite,

pyrite and galena. An unidentified mineral has been found in the galena.

Quartz, calcite and dark carbonates, in masses, stringers, and cracks, constitute the gangue. Fragments of wall rock are abundant.

#### Arsenopyrite.

There can be no doubt that arsenopyrite was the first sulphide to be deposited. It occurs as open space filling and as a replacement of quartzite wall rock fragments (fig. 7). In the former occurrence crystals up to several hundreds of microns are found (fig. 2); in the latter the mineral is much finer grained and a definite crystal outline is seldom traceable (fig. 1). If in section 3 the arsenopyrite is traversed from a quartzite fragment outwardly to the contact with quartz, a textural transition from fine to coarse grained is apparent. Overlapping of arsenopyrite and quartz depositions is shown by a few well-defined quartz crystals in the arsenopyrite near the border with quartz (fig. 2). The hand specimen shows vugs in the quartz at times filled with sphalerite and chalcopyrite; this fact gives a macroscopic proof of later deposition of quartz with respect to arsenopyrite. Disseminated crystals of arsenopyrite occur in the quartzite and their emanation from some channel is regularly traceable.

The relation of the arsenopyrite with later minerals will be described below.

### Pyrrhotite.

Pyrrhotite occurs in irregular but continuous masses contacting any of the minerals present in the ore. None of the sections happened to contain any pyrrhotite in contact with wall rock material, so that replacement of the latter by this mineral could not be observed.

Definite proofs of pyrrhotite being later than arsenopyrite have been found (fig. 3). The contact of the pyrrhotite with the arsenopyrite always follows the crystal outline of the latter. In a few cases small masses or single crystals of quartz separate the two minerals, showing priority of the quartz on the pyrrhotite.

Isolated blebs of pyrrhotite are often found in later minerals as an effect of undergone replacement. Pyrrhotite particles found in late fractures filled with carbonate gangue have all the characteristics of fragments and do not prove the existence of a second period of pyrrhotite mineralization.

### Sphalerite.

Four occurrences of this mineral are found, in two distinct generations. They all give deep red reflections under oblique light, showing that the sphalerite in question is of the iron rich variety called marmatite. ^

1. First generation:

(a) Irregular but continuous masses. Their contact with the pyrrhotite gives unmistakable signs of replacement of the latter. The contact with the arsenopyrite follows the crystal outline of this mineral; occasional small "caries" in the crystals show limited replacement of the arsenopyrite. The sphalerite masses contain exsolved *exsolved* chalcopyrite in rods following the crystal planes of the former mineral or in regularly distributed blobs.

(b) Beautiful exsolution stars in some of the chalcopyrite. Those shown in fig. 4 are typical and are also an example of the actual size range.

2. Second generation: *evidence*

(a) Extremely minute and ramified particles in marcasite, very seldom extending into the adjoining pyrrhotite (fig. 5).

(b) Particles up to 200 microns in size, replacing carbonate gangue in those same fractures that have been the avenue of the sphalerite that has replaced the marcasite.

Chalcopyrite.

Two generations of chalcopyrite are found and they seem to be in relation with the two generations of sphalerite.

1. First generation:

(a) Irregular but continuous masses carrying

exsolution bodies and stars of sphalerite (fig. 8). These masses seldom occur in direct contact with the quartzite; they are generally separated from it by a coating of calcite crystals 50 to 100 microns in size (fig. 6). The contact with the masses of calcite seems to follow the contour of the rhombohedral cleavage planes (fig. 7); this fact and the presence of some arsenopyrite crystals in the calcite show that the latter is earlier than the chalcopyrite.

(b) Exsolution rods and regularly spaced blebs in sphalerite (fig. 8).

## 2. Second generation:

Later chalcopyrite deposited with a dark carbonate in fractures cutting through pyrrhotite and sphalerite. It replaces the latter mineral preferentially to pyrrhotite; this replacement is particularly intense along the pyrrhotite sphalerite boundaries (fig. 9).

### Marcasite.

Marcasite is found along fractures filled with dark carbonate. It has replaced the pyrrhotite along the basal planes, and occurs in two varieties: one is white remarkably anisotropic, in lath-like crystals, and its total amount may be about 5% of the amount of pyrrhotite; it contains myriads of sphalerite particles (fig. 5) and may assay up to 25% zinc; the other variety, present in very minor amounts, is light brown, slightly anisotropic and shows

DK

colloform <sup>a</sup>bending (fig. 10); it is probably contemporaneous with the first and does not contain any sphalerite.

### Pyrite.

Pyrite has been identified only in section 7, where it occurs as 50-100 micron-crystals in a bluish carbonate. All the writer can say about age relationship is that the pyrite must be earlier than the galena; in fact it is sometimes replaced by the latter (fig. 11). If the token bluish carbonate were the same material found in the pyrrhotite cracks, the age of the pyrite would probably be the same as that of the marcasite. Also, the possibility cannot be excluded that the colloform marcasite above described could be pyrite.

### Galena.

Galena is found in patches from 20 microns to 1/2 cm in size, the largest ones occurring in the dark bluish carbonate and the smallest in the chalcopyrite and pyrrhotite. It is a replacement of sphalerite, chalcopyrite, carbonates, and, more rarely, of pyrrhotite, arsenopyrite and pyrite (fig. 11). In fig. 12 the galena seems to replace the pyrrhotite along the parting planes.

All the etch reactions have been tried on the galena of each section in order to insure its identity and bring out other eventual minerals: no inclusions have been evidenced by etching.

White mineral.

This mineral has been found only in the galena of section 1 (fig. 12). On a galena-white field it looks white with a tinge of pink. It has the same hardness as galena and is isotropic. The results of the etch tests are the following:

HgCl <sub>3</sub>	brown tarnish
KOH	dark tarnish
KCN	brings out some indefinite dark forms
HCl	brown tarnish
FeCl <sub>3</sub>	the mineral turns slowly black
HNO <sub>3</sub>	the mineral turns quickly black

*Alk group*

Dr. R. M. Thompson tried to remove a fragment of the mineral for an X-ray inspection but the small size of the particles found in the specimen made his attempt unsuccessful.

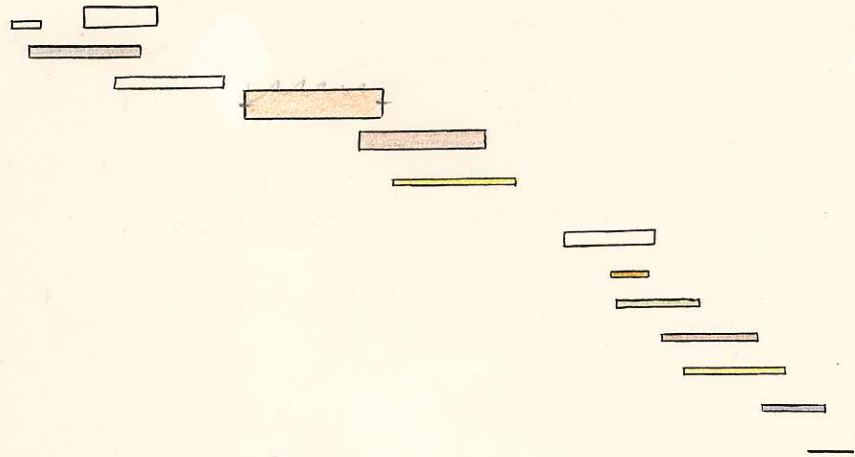
It is to be excluded that this mineral may be silver or electrum.

Observations and conclusions

In accordance with the foregoing evidences the following paragenesis is proposed.

Calcite  
 Arsenopyrite  
 Quartz  
 Pyrrhotite  
 Sphalerite  
 Chalcopyrite

Dark carbonate  
 Pyrite  
 Marcasite  
 Sphalerite  
 Chalcopyrite  
 Galena  
 White mineral



Such sequence should be accepted with some reserve because the writer has never seen the Mamie vein and essential facts apparent in the field may remain inconspicuous in a microscopic inspection. The thickness of the lines gives an idea of the relative quantities of each mineral present in the original sample, whose assay is: 14.74% Zn, .25% Cu, 14.51% Fe, 3.45%  $As_2O_3$ ,  $\uparrow$  oz./ton Au,  $\uparrow$  oz./ton Ag.

*still to be checked by Williams & Son*

The temperature of formation of the minerals deposited before the dark carbonate should be above  $350^{\circ}C$ ; in fact pyrrhotite forms above  $500^{\circ}$  (1) and exsolution of sphalerite in chalcopyrite or vice versa takes place between 550 and  $350^{\circ}C$  (2). The minerals that followed the dark carbonate formed at temperatures lower than  $300^{\circ}C$ , this being the upper limit for marcasite (1).



Since neither the precious metals nor their minerals have been observed, it was in the intention of the writer to have a fire assay run on each of the principal minerals. For this purpose a magnetic separation combined with superpanning was conducted. The details of the operation are given in Appendix II and may be used for future reference. The pyrrhotite, chalcopyrite and sphalerite obtained were of such a purity that neither the "ultra-pack" system of illumination applied to the ordinary microscope nor the binocular microscope revealed the presence of other minerals. Only the pyrrhotite however was obtained in sufficient quantity to be assayed. The results, as given by J. R. Williams & Son, are: .06 ounces per ton gold and 9.95 ounces per ton silver. Four possible reasons for such a high silver assay are proposed:

1. The compound  $\begin{matrix} \text{Fe} & \text{Ag} & \text{S} \\ 13.35+X & 1.65-X & 16 \end{matrix}$  is present in the pyrrhotite.

2. The galena found along the parting planes of the pyrrhotite is argentiferous; the galena blades are at times less than 10 microns wide and, likely, have not been completely separated from the pyrrhotite. Galena however can not carry in solution more than 32 ounces of silver per ton, and, in the amount found in the specimens, would never bring the assay of the pyrrhotite to almost ten ounces of silver per ton.

3. Some doubt about the identity of the galena is legitimate because at times the blades observed had the shape of exsolution bodies and, in the knowledge of the writer, no exsolution of galena in pyrrhotite has been described as yet. Also, colour, hardness and etch tests are not always exhaustive proofs in the determination of white soft minerals.

4. The unknown mineral, whose properties have been described on page 10 is a silver mineral and, with some of the galena, has escaped separation from the pyrrhotite.

Examination of the various sphalerite products from the most impure to the purest (see Appendix II) did not show any colour variation in the mineral; the difference in magnetic properties of the sphalerite was probably due to pyrrhotite inclusions rather than to a variable iron content; in fact some sphalerite-pyrrhotite middlings could be recognized in the products obtained at a current lower than the optimum, and sphalerite-gangue middlings in those obtained at a current higher than the optimum. It is also to be noted that the .65 amp-product, designated in Appendix II as clean sphalerite, contained at least 75% of all the sphalerite present in the original sample; the other 25% was mostly in the contiguous .6 and .7 amp-products. These results are diagnostic of practically constant iron content and are confirmed by the uniform deep-red colour of the internal reflections observed under oblique light.

The presence of a low-iron sphalerite would have added further evidence to the existence of a second sphalerite generation formed at lower temperature

From the microscopic examination and the above observations, the following conclusions may be drawn for what concerns flotation of the Mamie ore:

The separation of chalcopyrite from sphalerite, already difficult in itself, will be greatly impaired by the size of the particles resulted from reciprocal exsolution of the two minerals. The same may be said for the separation of galena from chalcopyrite, on account of the particle size of the galena replacing the chalcopyrite. Separation of galena from pyrrhotite may present difficulties; here, because of the amounts involved, the loss in lead should be negligible. Separation of sphalerite from marcasite will be impossible; every one percent marcasite in the tailings would add about .3% to their zinc assay.

In flotation, different iron content in sphalerite is characterized by different susceptibility of the mineral to the action of activating or modifying agents. The inconveniences often arising from this fact should not be

encountered in the treatment of the Mamie ore<sup>1</sup>.

Little can be said about the precious metals except that a substantial silver loss is unavoidable. To be specific, if 1/10 of the tailings were pyrrhotite, they would assay at least one ounce of silver to the ton.

The copper-lead concentrate from a flotation test has been superpanned, and the "tip" collected and made into a polished section. The same has been done with the second and fourth coarsest infrasizer products derived from the tailings of another flotation test. No free gold or electrum have been found. It is felt, however, that these sections should be re-ground and repolished several times, in order to inspect more than one layer of particles, before excluding the possibility of the presence of free precious metals.

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1 The writer takes this opportunity to correct a misleading statement made by him in his report "Investigation on flotation procedures for the Hummingbird and Mamie Ores", November 7, 1951:

"A fine, lighter coloured fraction of the sphalerite always floated faster than a fraction that appeared coarse, flaky and darker in colour".

Evidently, the different appearance and flotability of the two fractions were related to particle size and shape, and not to an intrinsic difference in colour (iron content).



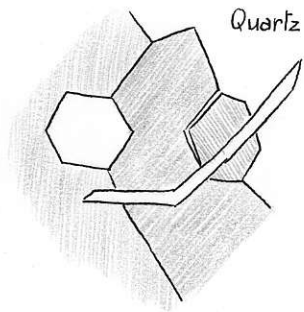
100 microns

Fig. 1

Arsenopyrite replacing quartzite (section 3) \*

Fig. 2

Quartz later than arsenopyrite. Some overlapping of deposition shown by the well defined quartz crystal (white) in the arsenopyrite. Some later quartz fills a crack crossing both arsenopyrite and quartz. (section 3)



100 microns

\* For the meaning of the colours see p. 11.

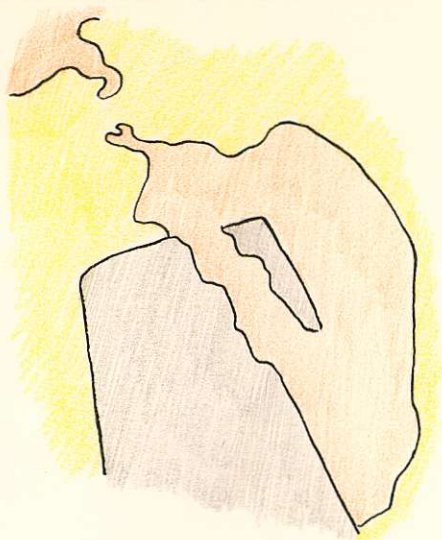
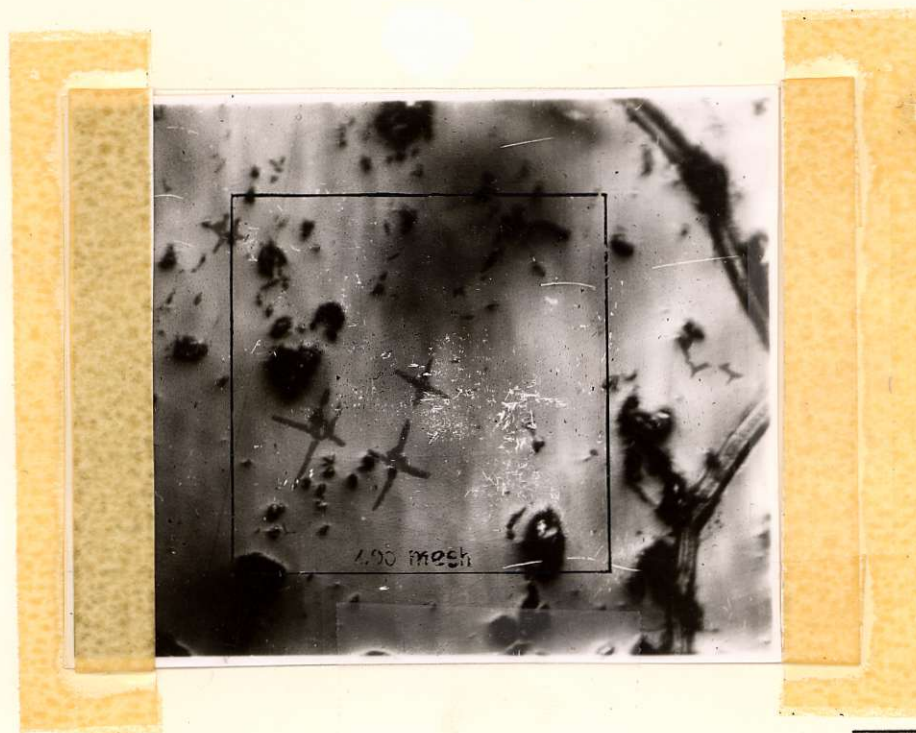


Fig. 3

Pyrrhotite later than  
arsenopyrite and chalcop-  
pyrite later than both  
(section 5)

—  
100 microns



—  
10 microns

Fig. 4

Exsolution stars of sphalerite in chalcopyrite (section 5)

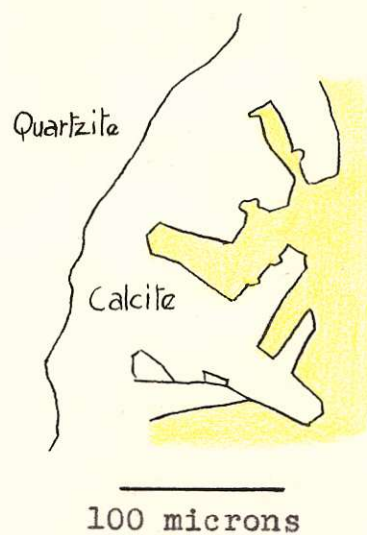


Fig. 5

Marcasite replacing pyrrhotite along the basal planes. Second generation of sphalerite replacing marcasite. (section 2B) (Under oil immersion).

Fig. 6

Coating of calcite crystals separating quartzite from chalcopryrite (section 9).





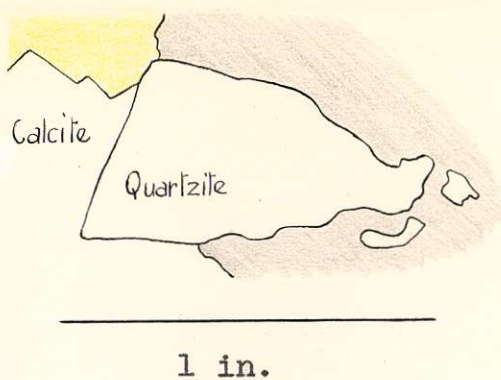


Fig. 7

Arsenopyrite replacing a quartzite fragment. Chalcopyrite following the contour of the cleavage planes of calcite (section 9).



Fig. 8

"Mutual boundaries", and reciprocal exsolution of chalcopyrite and sphalerite. Near the main contact a zone of pure chalcopyrite is encountered, beyond which exsolution stars of sphalerite in chalcopyrite appear. Similarly notice the absence of chalcopyrite in sphalerite near the main contact. (section 8).



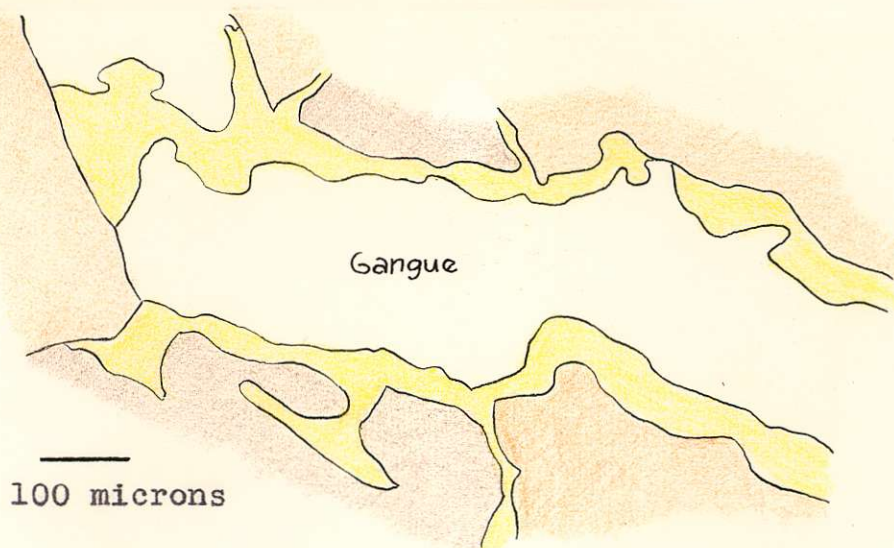
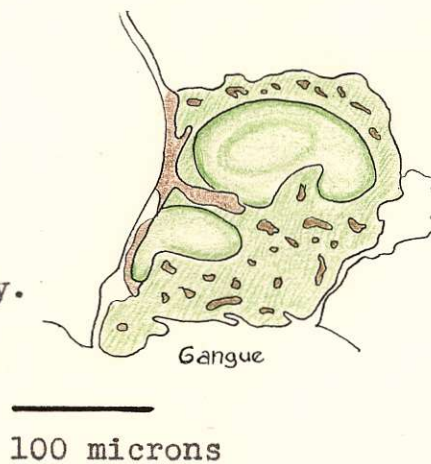


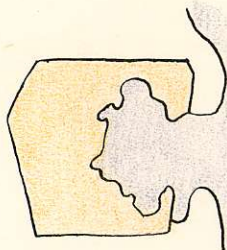
Fig. 9

Chalcopyrite replacing gangue preferentially to pyrrhotite (the two sides of the crack still match in the pyrrhotite). Chalcopyrite replacing sphalerite preferentially to gangue. (section 2).

Fig. 10

Colloform and crystalline marcasite. Sphalerite replaces only the latter variety. (section 2).





Gangue

10 microns

Fig. 11

Pyrite being replaced by galena (section 7)



100 microns

Fig. 12

Galena seems to replace pyrrhotite along the parting planes. The white unidentified mineral is marked with a cross (section 1).

*Have section  
repolished &  
examine*

A P P E N D I X

Appendix I - List of specimens

No. 1

Hand specimen.Size:  $2\frac{1}{2}$  x  $1\frac{1}{2}$  x 1"

Content: arsenopyrite (30%), pyrrhotite (30%), sphalerite (20%) and wall rock (15%).

Polished section.

Chalcopyrite and galena in pyrrhotite, arsenopyrite and sphalerite.

Sphalerite and galena in pyrrhotite and chalcopyrite.

A white unidentified mineral in galena.

No. 2 and 2b

Hand specimen.Size: 2 x  $1\frac{1}{2}$  x 1"

Content: pyrrhotite (90%) with some grains of sphalerite (5%), and chalcopyrite (3%).

Polished sections.

Sphalerite, galena, chalcopyrite and marcasite in pyrrhotite.

No. 3

Hand specimen.Size: 2 x 2 x  $\frac{1}{2}$ "

Content: coarse to fine grained arsenopyrite (40%), with crystalline quartz (35%) and wall rock fragments (30%). Some sphalerite and chalcopyrite in vugs of the quartz.

Polished section.

Two or three particles of chalcopyrite in arsenopyrite.

One particle of sphalerite in quartz.

## No. 4

Hand specimen.Size:  $2\frac{1}{2}$  x 2 x 1"

Content: solid cleavable sphalerite

Polished section.

Patches of galena, and blebs and rods of chalcopyrite in sphalerite.

## No. 5

Hand specimen.Size:  $1\frac{1}{4}$  x 1 x 1"

Content: chalcopyrite (60%) and pyrrhotite (30%).

Polished section.

Arsenopyrite, marcasite, sphalerite and galena in pyrrhotite and chalcopyrite.

## No. 6

Hand specimen

Size: 4 x 3 x 2

Content: arsenopyrite (25%), chalcopyrite (25%), calcite (25%) and wall rock (20%).

Polished section.

Sphalerite in chalcopyrite. Very few particles of chalcopyrite in arsenopyrite. Two particles of arsenopyrite in calcite.

## No. 7

Hand specimen.Size: 2 x  $1\frac{1}{2}$  x 1"

Content: galena (10%) in dark gray bluish carbonate.

Polished section.

Galena and pyrite in gangue.

No. 8

Hand specimen

Size:  $1\frac{1}{2}$  x 1 x 1"

Content: chalcopyrite (20%) and sphalerite (10%) in white and greenish quartzite.

Polished section

Sphalerite in chalcopyrite and vice-versa. Arsenopyrite in quartzite.

No. 9

Hand specimen.

Size: 4 x 2 x 1"

Content: chalcopyrite(20%), arsenopyrite(20%), calcite(30%) and quartzite(30%).

Polished section.

Arsenopyrite in quartzite and sphalerite in chalcopyrite.

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Appendix II - Separation of pyrrhotite,  
sphalerite and chalcop-  
pyrite for fire assaying.

Preliminary

360 grams of high grade ore were ground for 7 minutes in a laboratory mill with 30 pounds of rods. The ground product was screened by means of a Tyler set and the -150 +200 mesh portion was used for the magnetic separation; this size range was considered satisfactory because inspection with the binocular microscope revealed a fair separation of the minerals in the -65 +100 mesh portion.

Magnetic separation

After extraction by hand magnet of the bulk of the pyrrhotite, the product was run through the Frantz Isodynamic Separator;<sup>1</sup> the steps in the latter operation were the following:

- (a) .05-.2 amps, 20°N/25°W.<sup>2</sup> Cleaning from pyrrhotite.
- (b) .25 amps, 20°N/25°W. The first sphalerite appeared with calcite.
- .6 amps, 20°N/20°W. Mostly sphalerite.
- .65 amps, 20°N/25°W. Clean sphalerite.
- .7 amps, 20°N/20°W. Decreasing sphalerite.
- (c) .75 amps, 20°N/20°W. Little sphalerite, little chalcoppyrite.
- .85, .90, .95 amps, 20°N/20°W. Clean chalcoppyrite (no visible difference between the three products).

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1 Made by S.G.Frantz Co., N.Y.

2 N refers to the scale on the right side of the machine.  
W " " " " " " " " back of " "

- (d) 1.00-1.25 amps (20°N/20°W). Mostly gangue.  
1.25 amps (15°N/15°W). Still gangue. The arsenopyrite did not appear.

Magnetic cleaning.

The sphalerite taken out at .6 amps was cleaned at the same amperage and setting. Similarly the .85, .90, .95 amp-portions of chalcopyrite were cleaned each one at its amperage. Some of the gangue and middlings that had been mechanically entrained in the first separation were so discarded.

Cleaning by Gravity.

At this stage some calcite, probably containing pyrrhotite inclusions, was still visible under the microscope. The sphalerite and chalcopyrite, and the pyrrhotite first separated by hand magnet, were run through the superpanner. The tail and the tip of each product were discarded; the remainder was recovered for assaying.

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