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On the Ore Minerals of the Lower Ore Deposit of the Kawayama Mine, Yamaguchi Prefecture

By

Setsuo TAKENO

with 12 Text-figures and 4 Plates

ABSTRACT: The seemingly bedded deposit of cupriferous iron sulphide ores of the Kawayama mine locating in the Sangun metamorphic rocks is at present thought as if it were comprised in certain fractured zone connecting with thrust plane. The ores concerned are composed mainly of pyrrhotite with minor amounts of chalcopyrite, sphalerite and pyrite. Microscopically, arsenopyrite, marcasite, cubanite, valleriite, native bismuth and others are observable.

In this paper, both the textures and the paragenetic relations of ore minerals appeared in the lower part of the ore deposit are mainly described.

CONTENTS

I. INTRODUCTION

The Kawayama mine, situated about 40km north of Iwakuni City, Yamaguchi Prefecture, Southwest Japan, is one of the most important ones for the iron sulphide ores in Japan, producing about 30,000 tons monthly. The main ore body of this mine consists of a bed or lens of sulphide ores so far developed with a scale of more than 1200m along its strike-side and 600m along its dip-side. It was not until 1936 that, in spite of discovery of their outcrops about 300 years ago, certain amount of ores were worked on an industrial scale in this mine.

The geology in the environs of the Kawayama mine district was first described by KOJIMA (1947, 1950), according to whom "the district is cut by an overthrust named 'Kitayama overthrust' from SW to NE in the adjoining Sugane district……; the ore body concerned lies in the crushed zone along the hanging wall of the very thrust. The shape of the ore body is almost controlled by the thrust plane." Subsequently various works regarding the geology and ore deposit of the Kawayama mine have been accomplished (TAKASHIMA *et al.*, 1951; HONDA, 1950, 1952; NOMURA *et al.*, 1952; etc.), supporting Kojima's view to more or less extent with reference to the occurring style of the ore body.

As for the ore minerals of the Kawayama mine, GOHARA (1955) pointed out that, basing on paragenesis of the ore minerals and their textures, the Kawayama ore deposit corresponds to that of the hypothermal origin, while some authors (eg., TAKASHIMA *et al.*, 1951) indicated the association of ore deposit with some kinds of "skarn minerals" such as actinolite, garnet, hedenbergite and so on.

In the light of the preceding, the present author will hereunder deal with the heading.

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II. OUTLINE OF GEOLOGY

The geology distributed in the Kawayama district consists of crystalline schists, a part of the Sangun-Motoyama metamorphic group, and non-metamorphic Paleozoic formation. As was stated by KOJIMA (1947, 1950), the latter overlies conformably the former at Sugane-village west of the district, both being gradually shifted to each other. On the other hand, the upper non-metamorphic group, consists of alternation of slate and sandstone and the lower metamorphic group of graphite-schist accompanied with subordinate amount of green schist and sandstone schist. The rocks of the lower group gradually change to non-metamorphic towards the upper horizon.

The schists (mainly graphite-schist) in the lower group show commonly a distinct schistosity. Generally, the schistosity-plane designated as S_1 in this paper is parallel to the bedding plane. One of the conspicuous linear structure of the schists here termed L_1 is derived from fine crinkles on the S_1-surface, pointing regionally to northeast-southwest trend.

The ore bodies under consideration are intercalated in the transitional zone between the non-metamorphic and the crystalline schist groups. This stratigraphic horizon containing the ore bodies is characterized by thick beds of limestone.

Two large masses of green-rocks occurring in the area compose of coarse-grained albite-epidote-gabbro in the central parts and show schistosity in the margins, bearing synkinematic characteristics (KOJIMA and SASAKI, 1950).

Quartz-porphyry dikes representing the last igneous activity in the region are found exposed here and there within the area.

III. GENERAL STATEMENTS OF THE ORE DEPOSIT

The ore body in this mine is divided roughly into two parts: one is situated on the eastern side of the Higashi-dani fault and named the "upper deposit" while the other on the western side of the same fault is named the "lower deposit".

A. UPPER ORE DEPOSIT

The ore deposit of the Kawayama mine is, in general, bedded in form nearly parallel to S_1 of the country rocks consisting of the semi-schist. The ore bodies are accustomed to revealing a general strike of N40°～50°E in the southern part and N30°～40°W in the northern part, with dips of 5°～20°W. Their thickness is about five meters on an average, ranging from a few centimeters to some dozen meters.

As was referred to previously, the deposit in question has been believed to lie in the crushed zone or thrust zone. Basing on the mode of relationship between the sheared plane or zone containing the ore bodies and structures of crystalline schist system, MITSUNO (1960) classified a number of ore deposit of "Kieslager" type in the Sangun metamorphic zone of Eastern Chûgoku into two groups such as the Kieslager of "Besshi-type" and that of "Kawayama-type". Noteworthy is that the latter seems to be characterized by structural relationship similar to that pointed out by MITSUNO but more detailed researches concerning the upper deposit still remain to be dealt with in the future.

B. LOWER ORE DEPOSIT

In this paper, the writer will describe soley the "lower ore deposit." The related deposit with a scale of 120m～150m on its strike side and some hundred meters on its dip side is confined to a section of the ore body situating between the Higashi-dani fault and the Nishi-dani fault (see Fig. 1) (cf. NISHIZAWA, 1962, p. 5). The very deposit consisting of iron sulphide ores occurs almost in concordance with S_1 revealed in the wall rock of black-colored semi-schist. At the southeastern and the northwestern ends on the strike side the ore body is cut by the major faults mentioned above.

At a glance, the ore body bears a layered form in cross section both for strike and for dip, whereas detailed inspection indicates that there are innumerable partings in the ore bodies as well as in the wall rock. These partings are roughly conformable with each other but precisely often clinounconformable.

On the hanging wall along the uppermost drift situating on −180m level the banded ores are found predominant, the trend of the bands being almost parallel

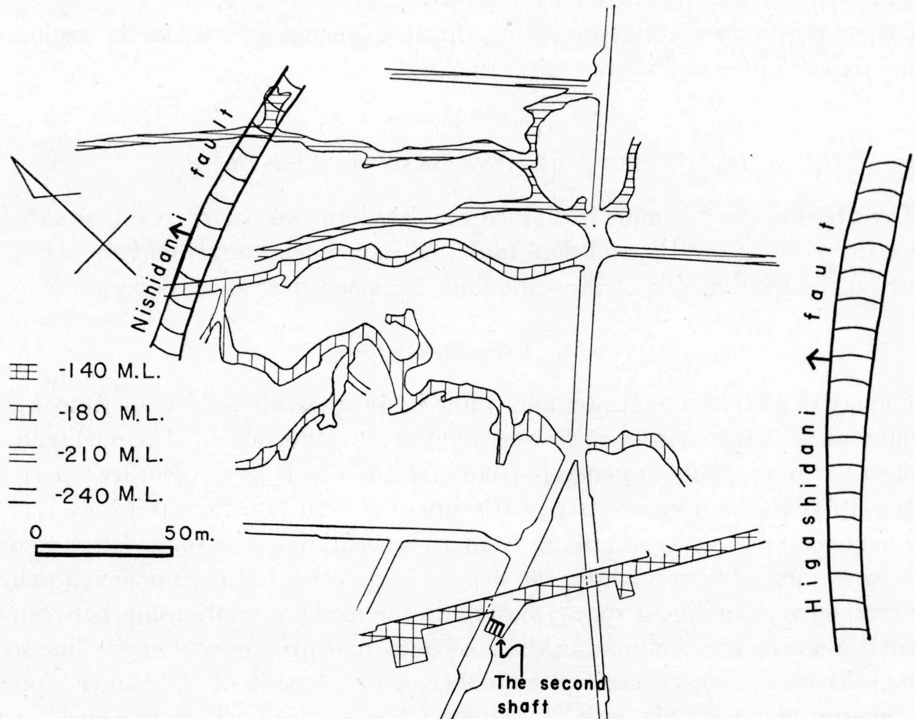

FIG. 1. The galleries of the lower deposit of the Kawayama mine.

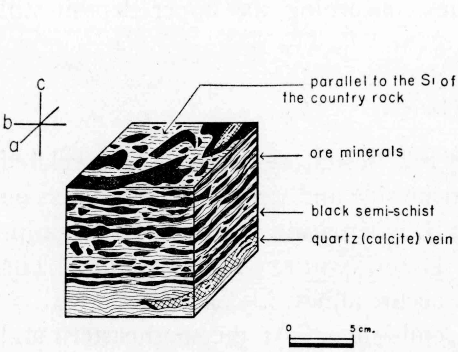

FIG. 2. Relation between the S_1-surface and the ore.

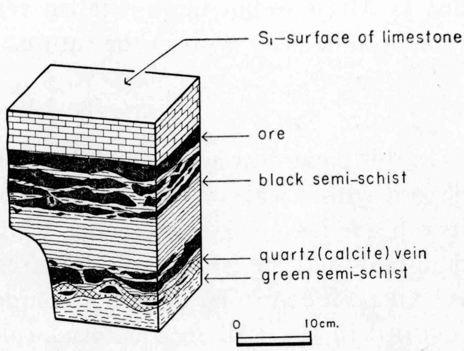

FIG. 3. Contact relation between the ore and limestone.

to S_1-surface of the wall rock. Fig. 2 shows this relation.

On the lowermost −240m level excavated in thick limestone, the relation of the ore bodies to the wall rock (limestone) is, in general, fairly concordant (see Fig. 3).

Generally, the boundary between the ore bodies and the wall rock is sharp but thin skarn zone and networks of veinlets are, in parts, observed between them. Of significance is that L_1 of the wall rock runs roughly parallel to the elongation direction of the ore shoot and is estimated nearly S60°W 23°.

IV. Ore Minerals

The ores are composed chiefly of massive compact pyrrhotite with a little amount of chalcopyrite and sphalerite, but locally of banded one or its networks. Pyrite, marcasite, arsenopyrite, galena, native bismuth, cubanite and valleriite are observed in small quantity, and stannite as well as wittichenite in very few specimens.

Most of the ore minerals in 400 specimens collected from 200 localities will be described in the following.

1. *Pyrrhotite*

The modes of occurrence or microscopic textures revealed by the minerals are distinguishable as follows:

a. Massive pyrrhotite

Massive pyrrhotite is most common. Mesoscopically, pyrrhotite is in general elongated along the direction of S_1 in *ac* and *bc* sections (see Fig. 4) and ordinarily not oriented in *ab* section (see Fig. 2), but sometimes elongated parallel to L_1 together with massive chalcopyrite or massive sphalerite, the former being demarcated with the latter two with boundaries. Protractile grains of pyrrhotite are 0.5mm ~2mm wide and 1mm~3mm long (see Plate 41).

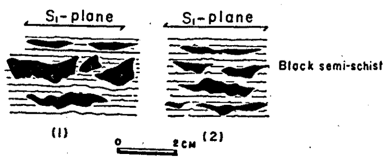

Fig. 4. Sulphide ores in *ac* (1) and *bc* (2) sections.

In parts, pyrrhotite pseudomorphs after pyrite (or arsenopyrite) are observed. Massive chalcopyrite and sphalerite are commonly included in massive pyrrhotite. Galena and arsenopyrite are rarely associated with massive pyrrhotite. Native bismuth and stannite are recognized in a few specimens. Sometimes sphalerite stars contained in small grains of chalcopyrite (-0.1mm) occur in massive pyrrhotite.

b. Shredded or shred-like texture

As is shown in Plate 41, pyrrhotite in massive sphalerite (rarely in massive chalcopyrite) occurs as tiny shreds with irregular shape of 0.01mm~0.05mm in size. These shreds, elipsoidal or rounded in form, are considered the product derived by replacement of the remnants.

In sphalerite, chalcopyrite shows the same texture.

c. Cell texture

In the lower deposit, cell or cellular textures (SCHWARTZ, 1951) of pyrrhotite are often observed in massive sphalerite (sometimes in chalcopyrite) and composed of small grains of pyrrhotite bearing a tendency pointing to certain orientation along crystallographic planes of sphalerite in their arrangement. The width of each blade or grain is ca. 0.005mm and its length is three to five times as long as the width on an average.

A zone of so-called "emulsion" texture, representing a sort of exsolution phenomena, of chalcopyrite accompanying valleriite is liable to appear by the pyrrhotite veins arranged along the definite direction. The exsolution bodies of pyrrhotite in sphalerite are shown in Plate 41.

d. Lattice texture

In a few specimens obtained from −240m level, lattice textures of pyrrhotite are observed in massive sphalerite. As is illustrated in Plate 41, each interval between lattices is about 0.2mm, and larger than that recognized in case of chalcopyrite. Minute blebs of chalcopyrite are scattered in the spaces of the lattices. Near the lattice texture, similar segregation-veins of pyrrhotite associating emulsion bodies of chalcopyrite are developed along several directions in massive sphalerite.

2. *Chalcopyrite*

Chalcopyrite is most universally associated with pyrrhotite. In the specimens obtained from −180m and −210m levels, chalcopyrite occurs commonly near the border of gangue minerals and pyrrhotite, and less commonly in massive pyrrhotite as small grains ranging from 1∼2cm to 10μ in size. On −240m level, chalcopyrite is comprised chiefly in massive sphalerite.

a. Massive chalcopyrite

Massive chalcopyrite comes into contact with massive sphalerite. Specimens sampled on −180m and −210m levels manifest the inclusion of the star-shaped or skeletal crystals, and veinlets of sphalerite in massive chalcopyrite. Moreover, chalcopyrite taken from the same levels is often used to accompanying galena, native bismuth and arsenopyrite near the gangue minerals. Massive chalcopyrite appeared on −240m level is, in general, associated with massive sphalerite in massive pyrrhotite and includes minute grains of native bismuth, cubanite, valleriite and skeletal crystals of sphalerite.

b. Shred-like and spotted texture

Shred-like textures of chalcopyrite are disclosed in massive pyrrhotite mainly on the upper two levels and in massive sphalerite, revealing irregular shapes of ca. 0.05mm in an average size. In this case, chalcopyrite bears no inclusion of skeletal sphalerite or native bismuth.

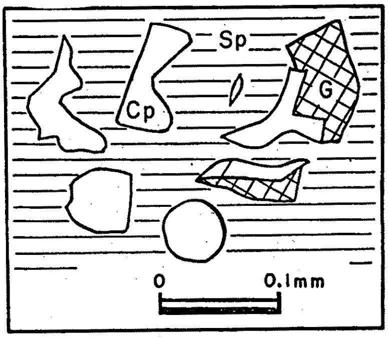

FIG. 5. Spotted and shred-like chalcopyrite. Cp: chalcopyrite, Sp: sphalerite, G: gangue.

In the specimens obtained from −240m level, spotted chalcopyrite with shape of ellipsoid and angular bleb is found sporadically in massive sphalerite and generally includes cubanite and valleriite. The size of chalcopyrite is variable from 0.01mm to 0.1mm (see Figs. 5 and 6).

c. Emulsion texture

A myriad of minute blebs or blades of chalcopyrite associated with valleriite are dispersed universally in massive sphalerite and, in relation to their mode of occurrence and shape, devided into two types: one is appeared as minute rounded ones (0.01mm) developed homogeneously and the other as angular or rounded ones (0.05 mm) distributed irregularly. In the latter case, cubanite is often observed included as minute grains. In a few specimens, inclusions of cubanite and valleriite are distributed in some crystallographically uncertain direction of sphalerite.

After SUGAKI (1952), chalcopyrite in this mine occurs in sphalerite as a) irregular or vein-shaped aggregates, b) lattice or chains of globules arranged crystallographically, c) small globules, from 1 to 10 microns in diameter, scattered in an emulsoidal form, and d) minuted dust, less than 1 micron in diameter, observable only under the microscope with oil emmersion lenses. He concluded that globular, dusty or lattice-shaped chalcopyrite in sphalerite was formed by unmixing from their solid solutions at temperatures from 350°C to 400°C.

d. Lattice-like texture

In some specimens from −180m and −210m levels, lattice-like textures of chalcopyrite are observed in massive sphalerite and less commonly in pyrrhotite, their arrangement being rather irregular or incomplete. Each blade of chalcopyrite composing the lattice is ca. 0.002mm in width (see Fig. 6).

On −240m level, segregation veins of chalcopyrite are often observed in massive sphalerite. There are fine emulsion bodies of chalcopyrite associating valleriite near the veins.

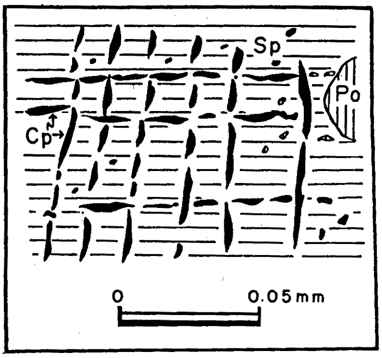

FIG. 6. Lattice-like texture of chalcopyrite. Cp: chalcopyrite, Po: pyrrhotite, Sp: sphalerite.

3. *Sphalerite*

Sphalerite becomes more abundant in amount with descending of the level and especially rich on −240m level, occurring in various modes similar to the preceding.

a. Massive sphalerite

Massive sphalerite is bounded mutually with massive pyrrhotite and massive chalcopyrite. On the upper two levels, it is often replaced by galena or chalcopyrite, while, on −240m level, it includes universally emulsion blebs of chalcopyrite and fine grains of pyrrhotite. Less commonly, massive sphalerite alone fills the interstices of gangue minerals (calcite or quartz).

Chalcopyrite blebs in massive sphalerite include cubanite and more frequently valleriite.

b. Cellular texture

In a few specimens collected from the two upper levels, cellular textures (SCHWARTZ, 1951) of sphalerite are observed in massive chalcopyrite (rarely in massive pyrrhotite), disclosing homogeneous or less commonly heterogeneous occurrence of irregular shaped sphalerite in chalcopyrite. Each blade, flake, and rod-like or angular grain is about 0.001mm to 0.05mm in its width. Emulsion-like blebs are developed near the cells, scattered more irregularly and heterogeneously and less common than in the case of chalcopyrite. In many parts far from the emulsion-like blebs, star-shaped or skeletal crystals of sphalerite are observed.

c. Veinlets and spots

It is difficult to classify the textures of fine-grained sphalerite crystals. A few veinlets of sphalerite with only a definite orientation are used to appearing commonly by the spotted sphalerite in chalcopyrite and rarely in pyrrhotite, differing from lattice-like ones of chalcopyrite and pyrrhotite with two directions in sphalerite.

In massive pyrrhotite, the veinlets are arranged along some crystallographic plane, while spots (0.001mm∼0.05mm) of sphalerite are rounded or ellipsoidal and,

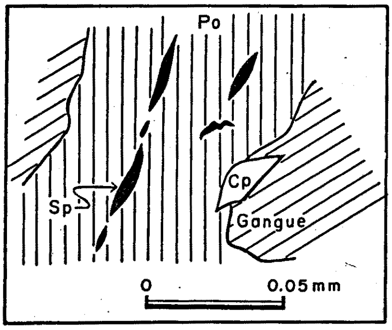

FIG. 7. Segregation vein of sphalerite. Sp: sphalerite, Po: pyrrhotite.

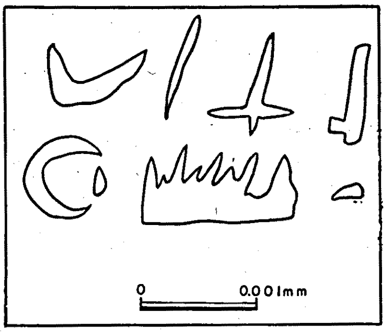

FIG. 8. Varieties of the shape of skeletal crystals of sphalerite.

in parts, elongated along some direction (see Fig. 7).

d. Star-shaped or skeletal crystals

Star-shaped or skeletal crystals of sphalerite often occur in massive, spotted and shred-like chalcopyrite, displaying various forms such as cross-like, three-forked, rectangular, needle-like or circular ones (see Fig. 8). The size of skeleton is more than ca. 0.001mm in length (see Plate 42).

4. *Cubanite*

Cubanite associated with valleriite is always observed in the grains of chalcopyrite enclosed in massive sphalerite.

Its modes of occurrence are rich in variety, as are shown in the following:

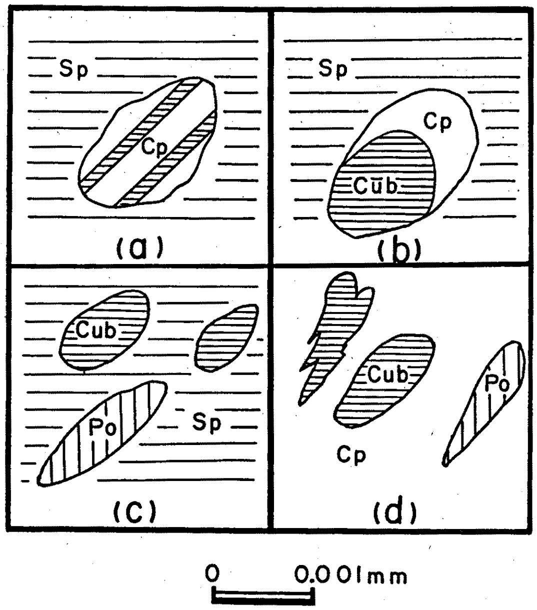

FIG. 9. Occurrences of cubanite. Cub: cubanite, Cp: chalcopyrite, Po: pyrrhotite, Sp: sphalerite.

a. The banded texture with chalcopyrite in a single grain of chalcopyrite (Fig. 9-a).

b. Rounded grains included in those of chalcopyrite (Fig. 9-b).

c. Minute grains involved simply in massive sphalerite (Fig. 9-c).

d. Grains comprised independently in massive chalcopyrite showing the boundary lines with pyrrhotite (Fig. 9-d).

e. The integrowths with valleriite in a single grain of chalcopyrite or with pyrrhotite in considerable amounts (Fig. 10-c and d).

In most cases, valleriite is contained in emulsion grains of chalcopyrite in the neighborhood of cubanite.

5. *Valleriite*

It is always intimately associated with chalcopyrite blebs in massive sphalerite and divided into two types in its occurrence: one is included in emulsoidal grains of chalcopyrite in massive sphalerite without cubanite (Fig. 10-a and b) and the other shows intimate intergrowths with cubanite in a single grain of chalcopyrite (Fig. 10-c and d).

In the former case, valleriite generally shows one or two orientations along some crystallographic planes of chalcopyrite but, in some specimens, no orientations and microscopically random extinction. Varieties in occurrences of valleriite are illustrated in Fig. 10.

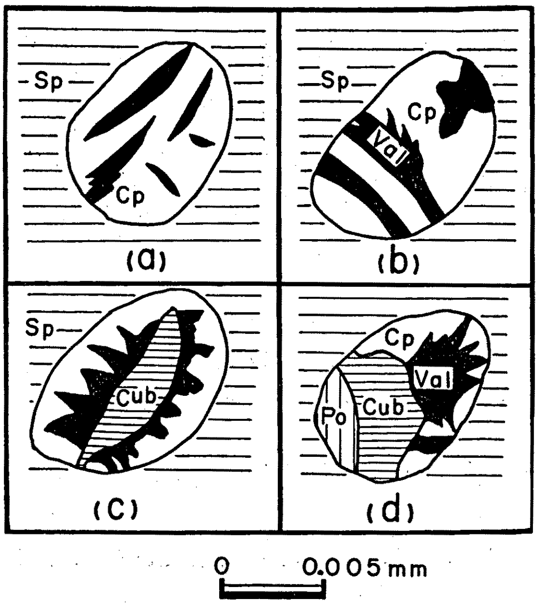

FIG. 10. Occurrences of valleriite. Val: valleriite, Cub: cubanite, Cp: chalcopyrite, Po: pyrrhotite, Sp: sphalerite.

6. *Galena*

Galena is observed frequently in a small amount in massive pyrrhotite, chalcopyrite and sphalerite and, in parts, alone in gangue minerals (quartz or calcite). In some specimens, grains of galena, ranging from 0.01mm to 0.5mm in size, are arranged along some directions as elongated veinlets (see Plate 43).

7. *Native bismuth*

In some specimens, minute grains of native bismuth, elongated or irregular, fine-grained in shape, are recognized in massive pyrrhotite, chalcopyrite and sphalerite and, in a few specimens, associated with extremely minute-grained minerals (less than 0.001mm in size) assumed as bismuthinite or wittichenite and rarely with cubanite (see Plate 43).

8. *Arsenopyrite*

It generally shows the contact with pyrite and pyrrhotite and occurs in, or nearby, pyrrhotite and chalcopyrite. It also distributes along the peripheries of chalcopyrite contained in massive pyrrhotite in some specimens rarely on −240m level and, in parts, as inclusions in pyrite.

8. *Pyrite and marcasite*

Pyrite is generally euhedral or subhedral. Its cracks or interstices are filled with, or replaced by, pyrrhotite, chalcopyrite, sphalerite and quartz or calcite rarely with rims left not replaced.

Pyrite produced secondarily are, in parts, observed coexisting with marcasite.

Marcasite, 0.05mm∼0.5mm in size, is comprised in cracks or interstices of pyrrhotite and scarce in quantity (cf. GOHARA, 1955). Crystals of pyrite are about 10∼20mm in size in the specimens from the upper deposit and ∼10mm in those from the lower deposit.

10. *Stannite and wittichenite*

These minerals are microscopically recognized in two or three specimens sampled from two lower levels.

a. Stannite

It is observed only as very tiny veinlets appeared along the peripheries of gangue minerals in massive pyrrhotite in three specimens from −180m level (see Fig. 11).

Its characters are as follows :

Color : brownish green in the air.

Reflection pleochroism : distinct.

Anisotropism under crossed nicols : rather strong, but slightly weaker than that of native bismuth.

Hardness : higher than chalcopyrite and lower than sphalerite.

Etching reaction : effervesces slowly and turns to brown-red in color with conc.

HNO_3, and negative for 35% HCl, 20% KCN and saturated KOH.

b. Wittichenite

It is observed in massive pyrrhotite in three specimens picked up from -180m and -210m levels and usually includes minute blebs of native bismuth.

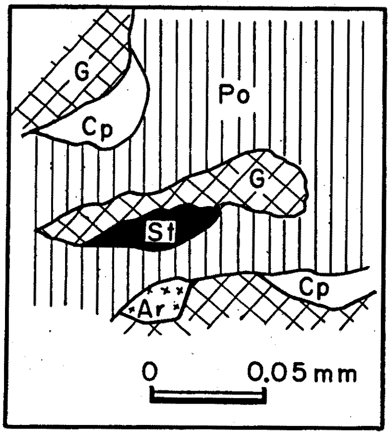

FIG. 11. Occurrence of stannite. St: stannite, Ar: arsenopyrite, G: gangue.

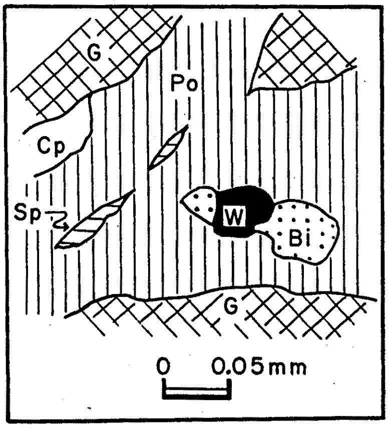

FIG. 12. Wittichenite in pyrrhotite. W: wittichenite, Bi: native bismuth.

Its characters are as follows :

Color : creamy white and much lighter than pyrrhotite.

Reflection pleochroism : recognizable in the air.

Anisotropism under crossed nicols : distinct but weaker than that of native bismuth.

Hardness : higher than native bismuth and distinctly lower pyrrhotite.

Etching reaction : slowly effervesces with 1 : 1 HNO_3, and negative for 35% HCl, 20% KCN and saturated $HgCl_2$.

11. *Gangue minerals*

Both megascopically and microscopically, quartz and calcite are the most common gangue minerals in the lower deposit.

In the country rock of green schist, white mica becomes more abundant with approaching to the ore body and chlorite decreases in the wall rock, and the green schist becomes pale-green in color.

In the megacrystals of quartz and calcite are included many infinitesimal relics such as sericite, chlorite, epidote and amphiboles (actinolite, tremolite and common hornblende).

Hisingerite is universally observed as the subordinate gangue mineral filling the interstices of pyrrhotite or quartz.

Roughly speaking, alteration of the wall rocks intercalated within the ore body is revealed in that, compared to those of the ore body, white mica generally decreases, while chlorite and quartz become more predominant.

Skarn minerals such as garnet, hedenbergite, epidote and amphiboles occur sporadically in the contact between the ores and the calcaleous rock.

V. Discussion

1. Previous works concerning the ore deposit of the Kawayama mine have hitherto been based mainly on its occurrence in the sheared or fractured zone assumed to appear in connection with the so-called Kitayama thrust. As far as its situation is merely concerned, the related views are considered to point to the reality to a certain extent, whereas it is also to be not neglected that the western extension of the ore body, here called the lower deposit, surely reveals a downward inclination oblique to an inferable level of the very thrust plane and develops in the depth more than some hundred meters deeper than the assumed level pertaining to the thrust. Moreover, any traces of shearing or fracturing are not proved to exist in the structures of wall rocks and of ore minerals.

As was described by Mitsuno (1960), an opinion of grouping this kind of ore deposit into a type of Kieslager only on the basis of its occurrence may also be significant in a sense but parallelism of the structures of wall rocks with those of ore minerals recognized in the ore deposit under consideration seems too low in grade to give a clue to such a classification.

2. As the ore minerals produced in this deposit, pyrrhotite, pyrite, chalcopyrite, sphalerite (including marmatite), and a few amount of cubanite, valleriite, stannite, native bismuth, Cu-Bi-S minerals, marcasite, galena and so on are mentionable.

As for the relationships between some pairs of these minerals, several researches have been carried into effect, as are shown in the following:

After Hewitt (1938), chalcopyrite dissolves in pyrrhotite at 600°C and exsolves again as laths on cooling although under different conditions of cooling copper component would be precipitated as chalcopyrrhotite and then converted to cubanite or valleriite since pyrrhotite dissolved in chalcopyrite above 300°C tends to react with chalcopyrite. Schwartz (1927, 1931) was of opinion that cubanite occurs only in a close association with pyrrhotite and chalcopyrite and Sn-bearing minerals are used to appearing as cassiterite in the pneumatolytic deposits but as sulphosalts at lower temperature. Edwards (1951) pointed out the complication in paragenetic relations among pyrrhotite, chalcopyrite, sphalerite and stannite. After Borchert (1934), skeletal crystals of sphalerite produce a sort of solid solution with chalcopyrite at temeratures from 480°C to 550°C, valleriite enclosed in chalcopyrite is able to react with the latter when heated above 225°C, and cubanite is conversible into a mixture of chalcopyrite and chalcopyrrhotite above 235°C.

Heat treatment made by Sugaki (1957) indicates that the skeletal sphalerite in chalcopyrite obtained from the Kawayama mine disappears perfectly when heated at 500°~550°C for 24 hours and homogeneous solid solution is obtainable when heated at 480°C for 48 hours and at 500°C for 24 hours. Occurrence of valleriite in Japan was reported first by TATSUMI (1953) from the Makimine mine, Miyazaki Prefecture and subseqently by TAKEUCHI *et al.* (1953, 1957) from Ômine and Akagane, Iwate Prefecture, by MATSUKUMA *et al.* (1957) from Obira, Ôita Prefecture and by MIYAHISA (1958) from the Besshi and Takara mines, Ehime Prefecture and by TAKEDA *et al.* (1960) from Sekizen, Ehime Prefecture. Moreover, TAKEUCHI *et al.* (1957) summarized also its occurrence in Tohoku District while SOEDA (1960) reported its content in pyrometasomatic deposits locating in Chûgoku District in relation to paragenesis with cubanite, indicating an intimate resemblance to that recognized in the lower deposit of the Kawayama mine. As for occurrence of cubanite in Japan, some works published by WATANABE (1937, 1940), TAKEUCHI *et al.* (1937a,1954a, 1955) and NAKAMURA (1949) are noteworthy but details of its occurrence in the Kawayama mine still remains to be scrutinized. Studies concerning stannite in the Ikuno, Ashio, and Besshi mines were executed by SHIMADA *et al.* (1962), and its mode of occurrence was divided by WATANABE (1951) into two types: one is dark green in color, weakly anisotropic and usually occurs in hydrothermal deposit, while the other is brown-colored, strongly anisotropic, and produced in xenothermal deposit. Merely as for this regard, the specimen sampled in the Kawayama deposit is to be grouped into the former type. In relation to Cu-Bi-sulphide, NUFFIELD (1947) considered klaprothite as a variety of wittichenite, emplectite and others, and wittichenite reported by NAKAMURA (1951) from the Ashio mine, Tochigi Prefecture resembles the specimen observed on −180 m level of the lower ore deposit under consideration either in optic characters or in etching reactions.

The data resulted from thermal procedures concerning exsolution appeared in some pairs of minerals have so far been liable to being provided as an indicator of temperature in the process of ore formation. Nevertheless, it seems still problematical whether or not the experiments put into operation may be applied to the natural occurrence of ore minerals in complicated state.

On the other hand, the results obtained by the present author as well as several works referred to already in the preceding are connected with paragenesis of ore minerals and their micro-textures merely in such a condition that the related process of mineralization is considered almost simultaneous or to have not been repeated or overlapped at all. Taking into account of the presence of the veinlets cutting across the main ore bodies, of low-temperature hydrothermal minerals, and of skarn minerals, recognizable in the deposit concerned, respective stages or, at least, steps representing each mineralogenesis are to be pursued in more details.

3. With respect to essential classification of the deposit in question, previous works have concerned simply its spacial situation or apparent structural relation on the whole, rather regardless of mineralic constituents, their lateral and vertical varia-

tions, their behavior in the wall rocks, respective series of their genesis, alteration or other phenomena appeared in the wall rocks situating by, or comming into contact with, the ore bodies. In some cases, more or less amount of special species of mineral, for instance, of pyrrhotite, included in Kieslager in certain localities have also been taken as a factor in classification of the ore deposit but are considered accountably due to difference of the space or horizon effective for ore formation if the related mineralizer is inferred to have moved from anywhere else. Because of importance of the theme, furthermore researches concerning this regard is to be promoted.

4. Micro-grained or scarce minerals such as wittichenite, stannite, valleriite, bismuthinite, native bismuth and some others, though identified at present microscopically through ordinary procedures owing to difficulty of sampling, still remain to be more accurately confirmed by any other means.

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EXPLANATION OF PLATE XLI

FIG. 1. Elongated pyrrhotite in a direction of the L_1 (*ab* section).
FIG. 2. Elongated pyrrhotite in a direction of the S_1 (*ac* section).
FIG. 3. Pyrrhotite replaced pyrite, leaving rim unreplaced (*ac* secion).
FIG. 4. Lattice texture of pyrrhotite (*ab* section).
FIG. 5. Shred-like texture of pyrrhotite in massive sphalerite (*ab* section).
FIG. 6. Pyrrhotite arranged in some direction of crystallographic plane of sphalerite (*ab* section).

Cp: chalcopyrite, Po: pyrrhotite, Py: pyrite, Sp: sphalerite, G: gangue.

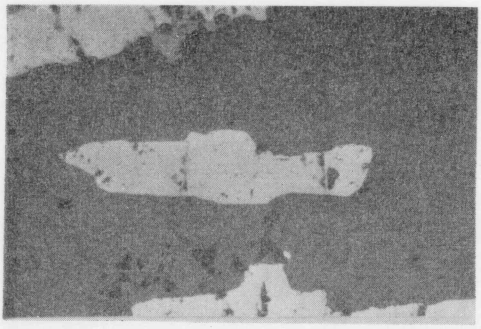

FIG. 1.

0 0.5 mm

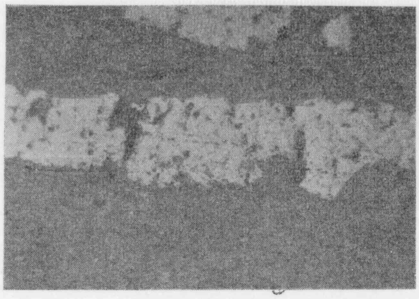

FIG. 2

0 1 mm

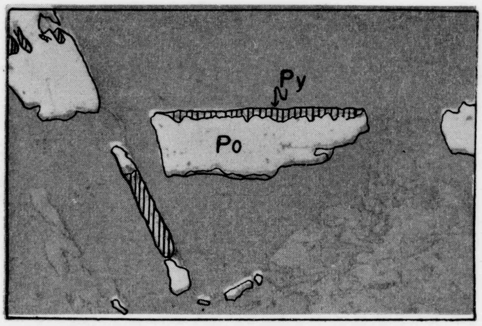

FIG. 3.

0 0.5 mm

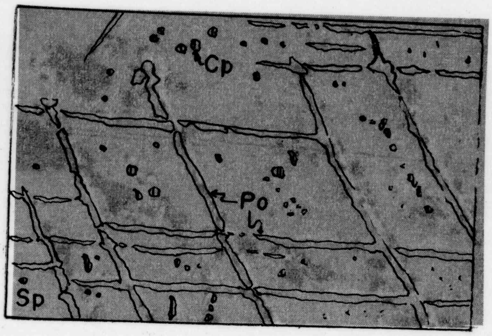

FIG. 4

0 0.2 mm

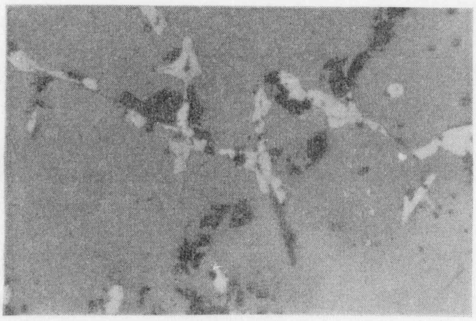

FIG. 5.

0 0.05 mm

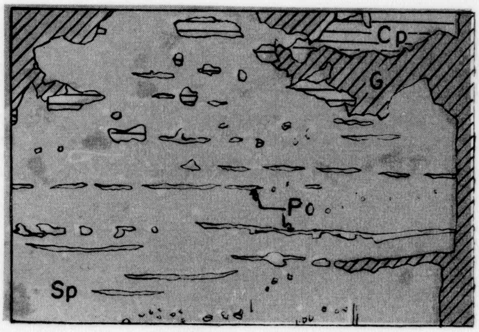

FIG. 6.

0 0.1 mm

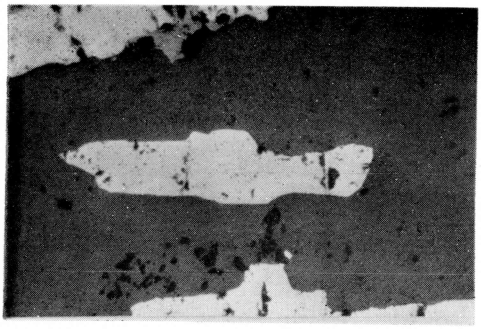

FIG. 1.

FIG. 2

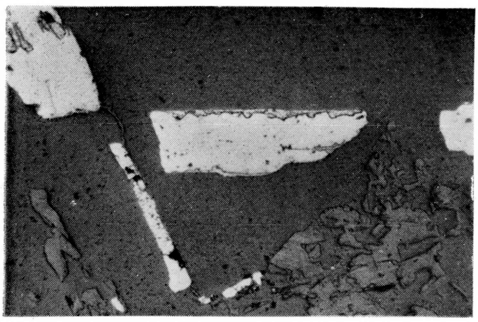

FIG. 3.

FIG. 4.

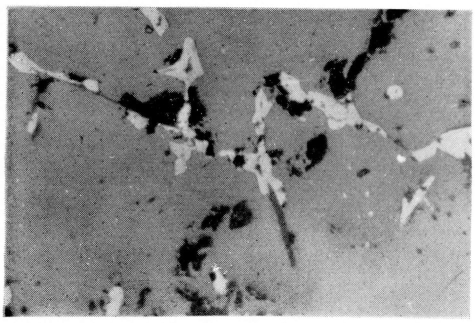

FIG. 5.

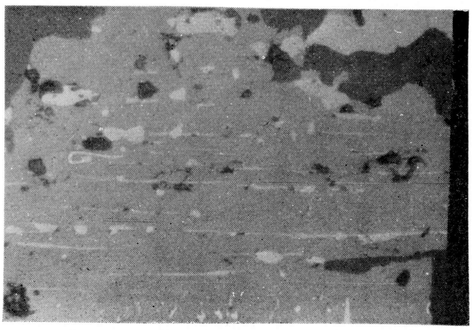

FIG. 6.

Explanation of Plate XLII

Fig. 1. Segreation veins of chalcopyrite in massive sphalerite. Adjacent to the veins there is a zone of fine "emulsion" exsolution bodies of chalcopyrite.

Fig. 2. Shred-like texture of chalcopyrite in a zone of emulsion bodies of chalcopyrite in massive sphalerite.

Fig. 3. Segregation veins of pyrrhotite in a zone of fine emulsion bodies of chalcopyrite.

Fig. 4. Segregation vein and spotted grains of chalcopyrite associated with cubanite.

Fig. 5. Spotted sphalerite in chalcopyrite.

Fig. 6. Skeletal crystals of spalerite in chalcopyrite.

Cp: chalcopyrite, Cu: cubanite, Po: pyrrhotite, Sp: sphalerite, Va: valleriite, G: gangue.

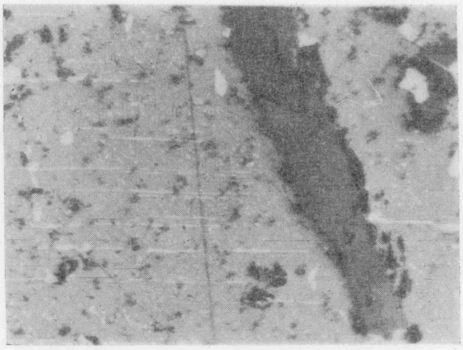

FIG. 1.

0 0.05 mm

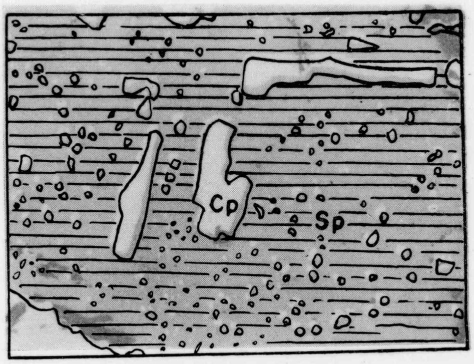

FIG. 2.

0 0.05 mm

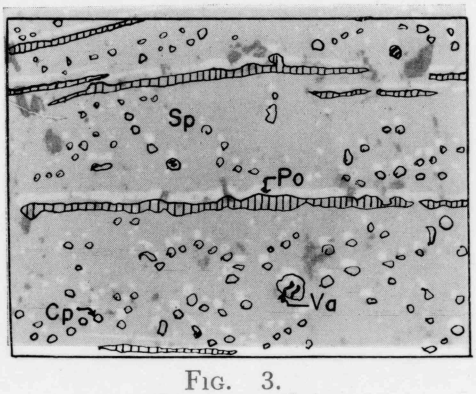

FIG. 3.

0 0.1 mm

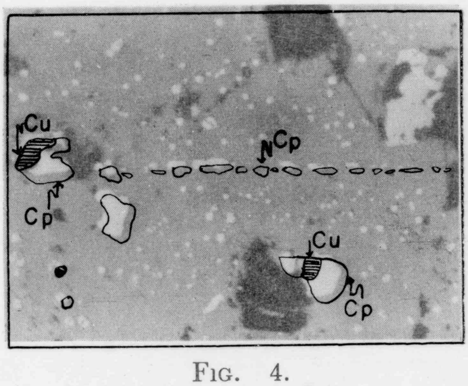

FIG. 4.

0 0.1 mm

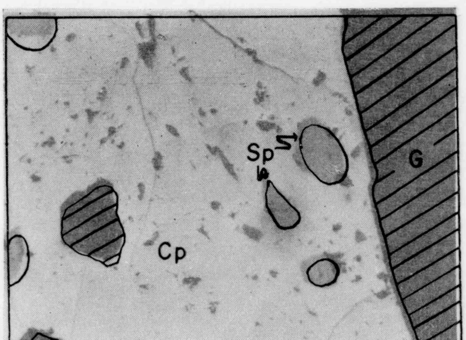

FIG. 5.

0 0.1 mm

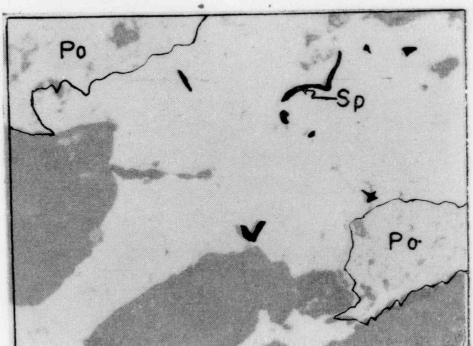

FIG. 6

0 0.02 mm

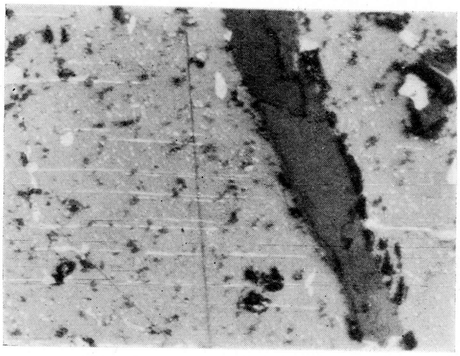

FIG. 1.

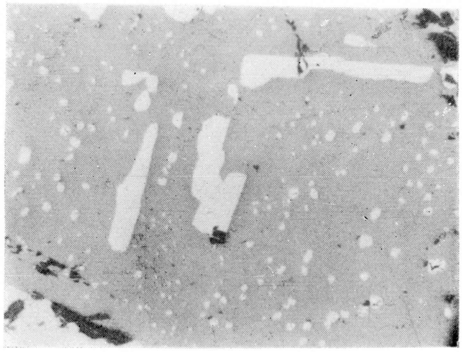

FIG. 2.

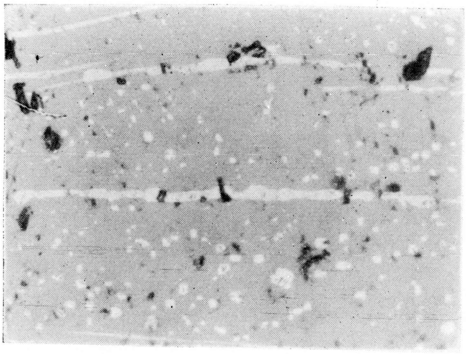

FIG. 3.

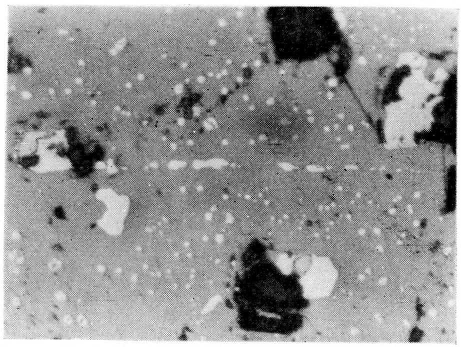

FIG. 4.

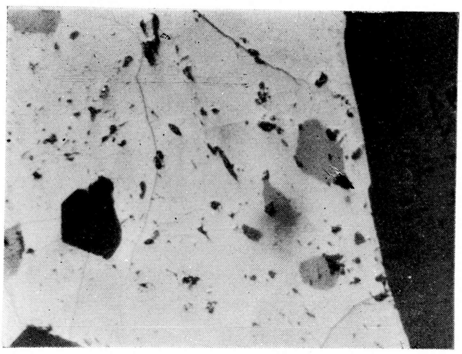

FIG. 5.

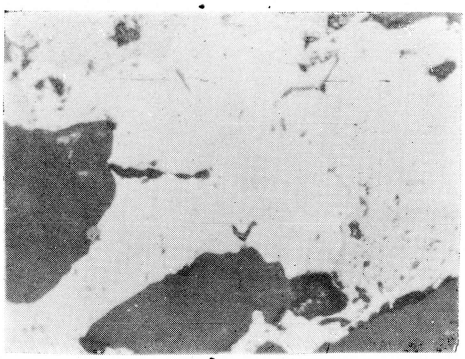

FIG. 6.

Explanation of Plate XLIII

Figs. 1, 2 and 3. Skeletal crystals of sphalerite in chalcopyrite.
Fig. 4. Intergrowth of cubanite and valleriite in a chalcopyrite grain.
Fig. 5. Cubanite and valleriite in chalcopyrite grains.
Fig. 6. Valleriite in chalcopyrite.
Fig. 7. Intergrowths of sphalerite, chalcopyrite, cubanite and valleriite.

Cp: chalcopyrite, Cu: cubanite, Po: pyrrhotite,
Sp: sphalerite, Va: valleriite, G: gangue.

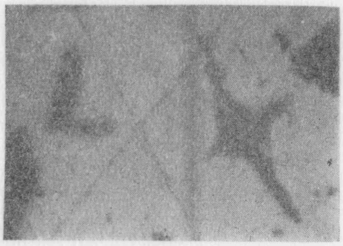

FIG. 1.

FIG. 2. 0 0.02mm

FIG. 3.

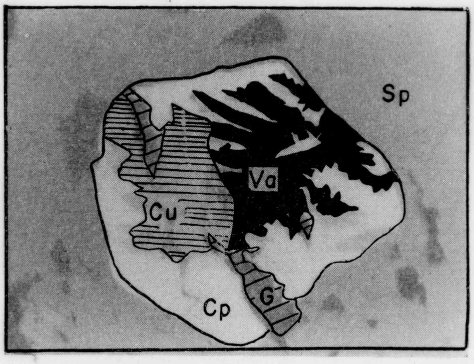

FIG. 4. 0 0.03mm

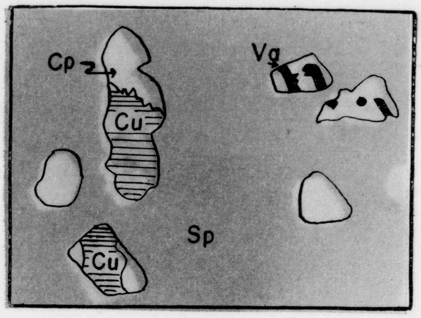

FIG. 5. 0 0.02mm

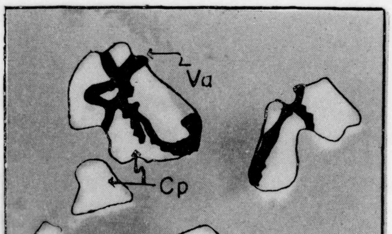

FIG. 6. 0 0.02mm

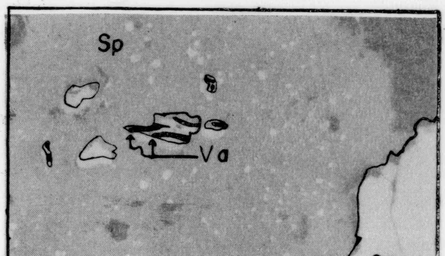

FIG. 7. 0 0.05mm

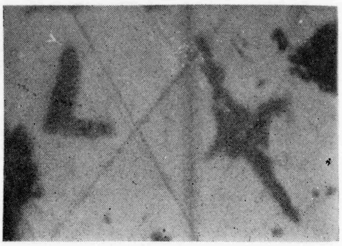

FIG. 1.

FIG. 2.

FIG. 3.

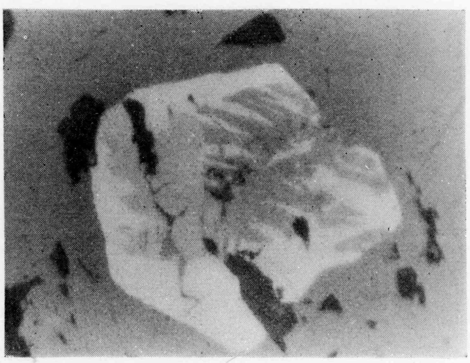

FIG. 4.

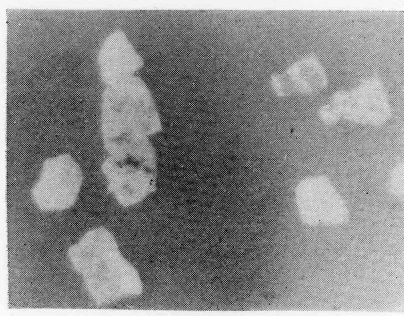

FIG. 5.

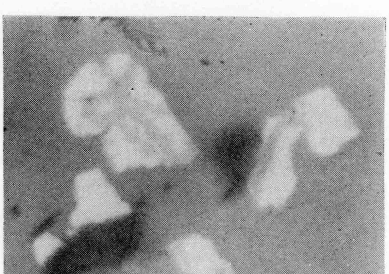

FIG. 6.

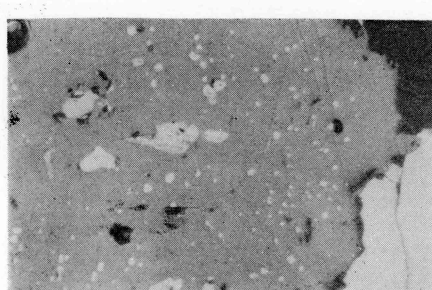

FIG. 7.

Explanation of Plate XLIV

Fig. 1. Cubanite in sphalerite with segregation veins of pyrrhotite.
Fig. 2. Oriented galena and native bismuth in pyrrhotite.
Fig. 3. Native bismuth with cubanite in sphalerite.
Fig. 4. Stannite in pyrrhotite.
Fig. 5. Pyrite and marcasite in pyrrhotite.
Fig. 6. Wittichenite with native bismuth in massive pyrrhotite. Crossed nicols.

Bi: native bismuth, Cp: chalcopyrite, Cu: cubanite, Ga: galena, M: marcasite, Po: pyrrhotite, Py: pyrite, Sp: sphalerite, St: stannite, W: wittichenite, G: gangue.

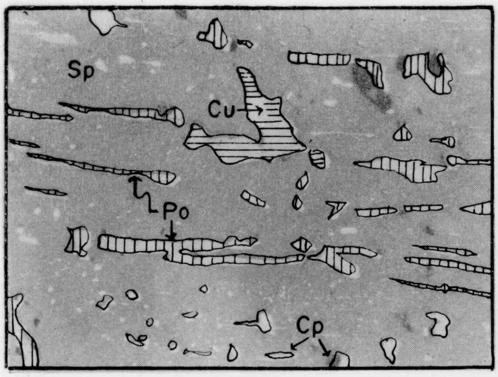

FIG. 1.

0 0.05mm

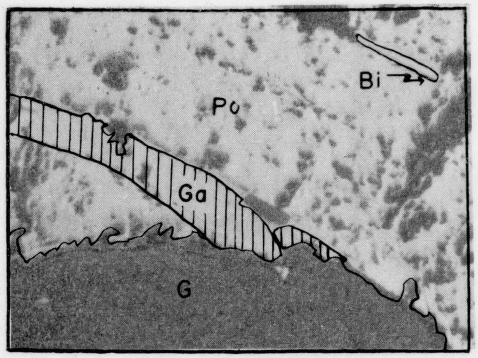

FIG. 2.

0 0.05mm

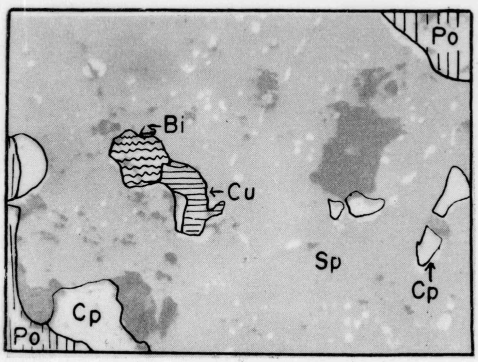

FIG. 3.

0 0.02mm

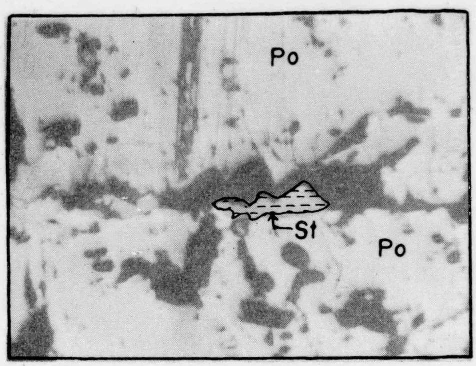

FIG. 4.

0 0.05mm

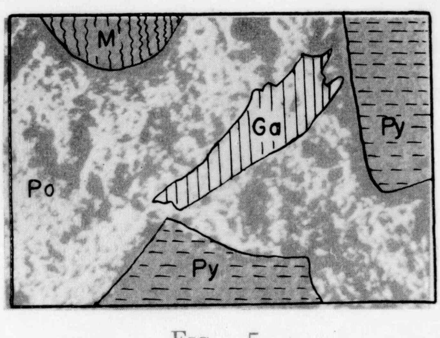

FIG. 5.

0 0.1mm

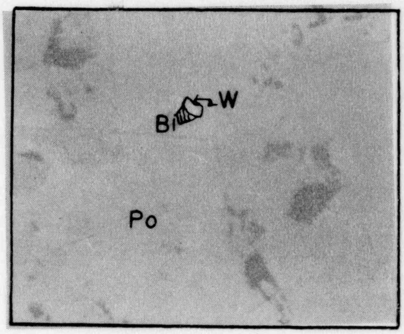

FIG. 6.

0 0.01mm

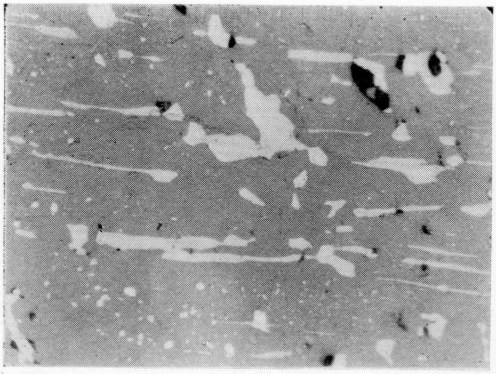

FIG. 1.

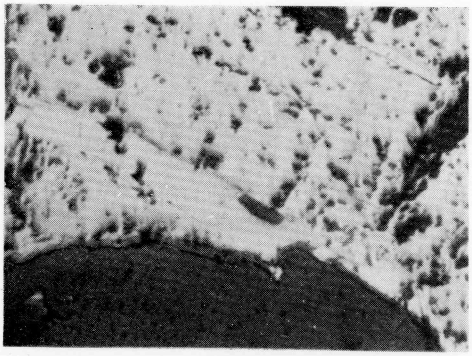

FIG. 2.

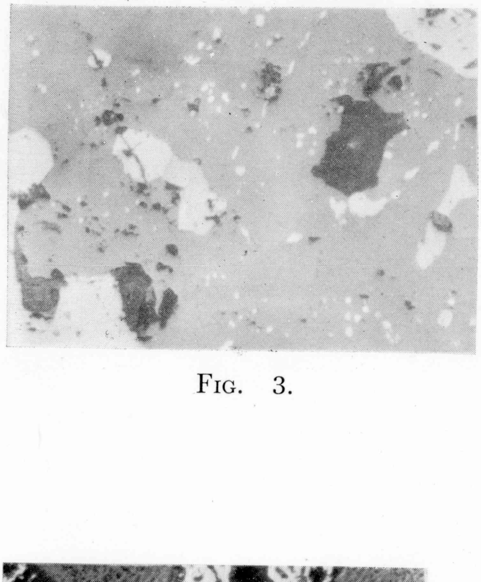

FIG. 3.

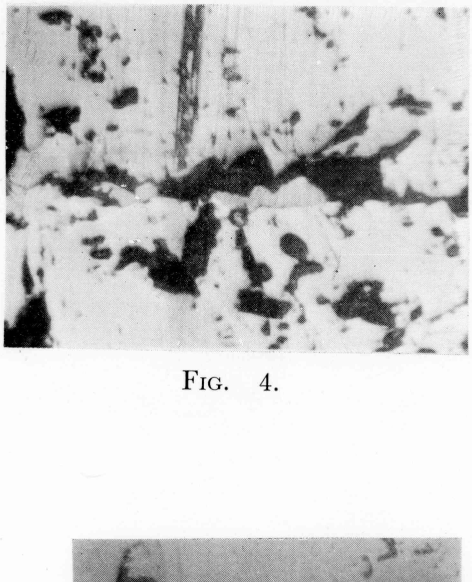

FIG. 4.

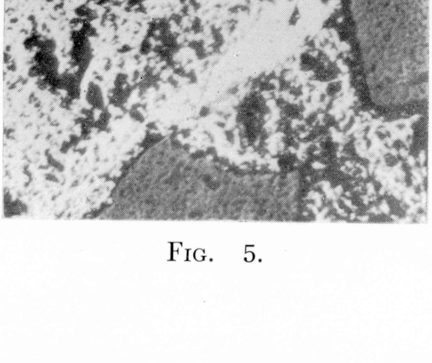

FIG. 5.

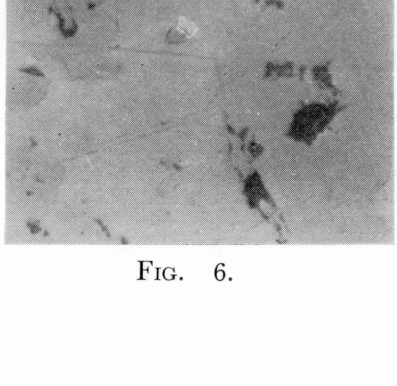

FIG. 6.