# A Sn-Te-Bi-Sb PARAGENESIS IN ORES FROM THE SUTTSU MINE, HOKKAIDÔ

(Study of the minor minerals of ore. Rept. 3)

By

Masao ISHIBASHI

(With Figs. 4 and Plate 1)

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## Introduction

The Suttsu mine, at Suttsu-machi, Shiribeshi-district, southwestern Hokkaidô, is situated immediately northwest of the Suttsu depot, a terminus of Suttsu railway line, which is about 15 km north from the Kuromatsunai station on the Hakodate-Sapporo line.

It was reported that Tasaburô IMAYA discovered the outcrops of these deposits in 1892. The mining right was transferred to the Takeda Mining Co., which was prospected and worked near surface as a silver copper mine. From 1914 till 1922 this mine was under the management of the Takata and Co., and worked for lead and zinc. At this time the deposits were thought to be a deposition of black-ore types.[3] Since 1934 the Taihei (former Mitsubishi) Mining Co, Ltd. has exploited and developed intensely these deposits, worked for lead, zinc and iron-sulphide.


Fig. 1.

The deposits of this mine are pyrite quartz veins containing sphalerite. The ore very often contains galena, and some copper minerals. Recently Mr. T. MIYAKE[11] described a number of interesting copper minerals, such as stannite, famatinite, tetrahedrite and luzonite from this mine. Since then the present writer has had opportunities to make a geological survey of this mine, and to collect many samples of ores which were studied microscopically. A few additional facts could be found. The purpose of this paper is to present the results of this study.

Grateful acknowledgement is due to Prof. Dr. Z. HARADA, Hokkaidô University and Prof. Dr. T. WATANABE, Tokyô University for their criticisms. Indebtness to the staff of the Suttsu mine is also acknowledged, expecially to Messrs A. NAKAMOTO, M. WATANABE and T. HARA who gave helpful suggestions and collections, and to Messrs H. OHMACHI and T. KIKUCHI who aided in the field work.

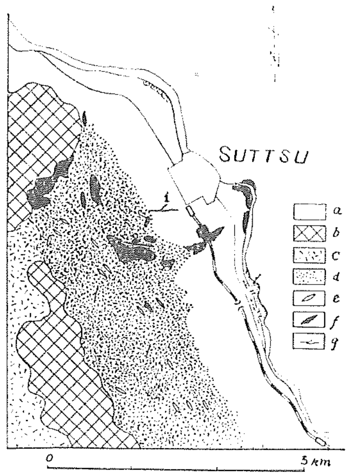


Fig. 2. Geological sketch map of the Suttsu area (by OHMACHI and KIKUCHI)
a : Diluvium b : Lava flow
c : Pliocene pyroclastic sediments
d : Miocene green tuff
e : Augite andesite
f : Hornblende andesite
g : Ore deposits
1 : The Suttsu mine
2 : The Seiso mine

## Geology and ore deposits

*Geology.* According to F. CHIBA,[2] K. OHMACHI,[13] T. KIKUCHI and others,[18] the mine area is composed of the Kunnui green tuff series (Miocene), the Kuromatsunai volcanic flows and pyroclastic rocks series (Pliocene), while a thin marine terrace deposit (Diluvium) covers them.

The "Kunnui series" enclosing the ore deposits consists mainly of green or greenish white colored tuffs, tuff breccias, agglomerates and shales that strike N 20° E and dip 10°–20° N W. These rocks are intruded by many small dikes of propylitized hornblendebearing augite andesite and augite andesite of different age. Among these dikes hornblende bearing augite andesite dikes, which include characteristically abundant cognate xenoliths, seem to have the very close genetical relationships with the deposition of ore, for in this area some pyrite quartz veins and pyrite impregnated low grade ores are often found in the green tuffs adjacent to those dikes, and in the dikes themselves.

*Ore deposits* Formerly the deposit had been classified as the impregnated and replaced black-ore type when it was exploited at near surface,(3)(12) According K. KINOSHITA it was also included as a vein type of "black ore deposits" in recent broader sense.(9)

The principal vein and several subsidiary veins strike EW extending about 350 m and dip from vertical to steeply south. And a larger NE vein branches off from about middle part of the principal vein. Mainly the principal vein has been exploited for about 250 m along the strike through a vertical range of 180 m.

The principal and most of subsidiary veins are composite veins consisting generally of two or three thin lenticular short lenses of vein which separate from and adjoin to each other. The lenticular veins range from 30 to 50 cm in thickness and extend some tens of metres. Often the branches take the form of parallel subsidiary veins constructed of complex and irregular hummock or looped structure.

Almost all veins are pyrite quartz ones; they are conspicuously rich in common sulphide minerals except the Ohkubo vein in question. The ores of pyrite quartz vein consisting of pyrite with or without sphalerite show granular massive, but often banded structure with pyrite, sphalerite and galena, and rarely are brecciated with which fragments of pyrite or sphalerite are cemented by quartz or Mn-calcite. In the vugs of veins are often found crystals of pyrite, gypsum, barite or calcite which are covered by clay minerals. The tenor of ore averages now about silver 110 gram per ton, lead 4.5% zinc 9.7% and sulphur 29%.

The Ohkubo vein in question that strikes EW and dips 80°N was considered at first as a branch of the principal vein. They are very much alike in texture and mineral composition. But they are rather dissimilar at the western part 105 m from the plat on the No. 5 sublevel, for the Ohkubo vein at this part becomes dark violet gray compact siliceous mass with rich in Cu-minerals. The Ohkubo vein is not yet ajoint with but runs parallel to the principal vein.

The tuff, tuff breccia and shale close to the veins are altered by chloritization, pyritization, kaolinization and silicification. Among these alterations of country rocks silicification and kaolinization are most common but limited to the close periphery of the ore bodies, while chloritization and pyritization are a little more widely developed.

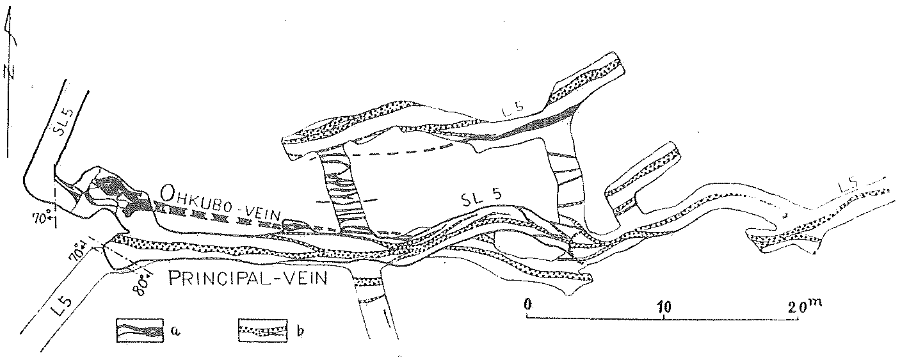


Fig. 3. Horizontal plan of ore bodies on No. 5. sublevel (80 m level) and No. 5 level (85 m level)
a : Siliceous Vein b : Sulphide Vein

## Pagagenesis

Ore minerals constituting the principal vein, subsidiary veins and branches are pyrite, sphalerite, galena, chalcopyrite and hematite, and the gangue minerals are quartz, Mn-calcite, barite, gypsum and clay minerals.

*Pyrite* is idiomorphic and hypidiomorphic granular (0.5–0.01 mm), and it often replaced or veined by sphalerite, chalcopyrite and galena.

*Sphalerite* shows various modes of appearance. Generally it is granular (2–0.5 mm) with brownish color, but sometimes dark brown, pale brown or zoned variations occur. Sphalerite from banded ore shows frequently feathery or acicular wurtzite-like form (10–3 mm long) with which galena always associates. Darker sphalerite has commonly numerous minute inclusions of chalcopyrite, famatinite, stannite and pyrite.

*Galena* is granular (5-0.5 mm) and massive, and it replaces pyrite, sphalerite and chalcopyrite. Galena mass seems to be found at limited vicinities along the adjointing parts of branches. Galena is often covered by thin crusts of fine granular pyrite which has nuclei of marcasite (Pl. I. 8).

*Chalcopyrite* is fine granular (ca. 0.1 mm) and sporadically found with pyrite and galena, and replaced by the latter.

Acicular crystals of *stibnite* are also noticed in the pyritic clay part of NE vein on No. 2 level.

General and widespread type of ore of this deposit may be represented by the association of the $FeS_2$-Pb-Zn (Cu) paragenesis, and in this mineralization the closest sets of associations of minerals are determined as follows:

$FeS_2$-Pb-Zn-(Cu) Mineralization

(1) Chalcopyrite-pyrite-barite
(2) Pyrite-sphalerite
(3) Galena-pyrite-Mn-calcite
(4) Marcasite-pyrite-barite-gypsum

Above described paragenesis is obviously a lower temperature formation. It occurs commonly in the green tuff series in the metallogenetic province of SW-Hokkaidô and almost all of such deposits have been rather conventionally included in the type of "black ore deposits".

*Ohkubo vein* is generally siliceous with banded texture. Especially at the narrow parts of the veins, are observed conspicuous bands of different mineral assemblages. In most cases the closest layer to the wall rocks is a dark gray siliceous one including cassiterite, and the next layer is brownish or violet gray consisting of stannite and famatinite. Then come sulphide bands consisting of yellow layer of chalcopyrite and pyrite, gray layer of sphalerite and galena, and creamy yellow layer of pyrite from siliceous salband toward the central vugs of the vein (Fig. 4, a).

At the wide parts of the vein the banded texture is found only at the marginal rims of the vein, and the remaining portion of whole

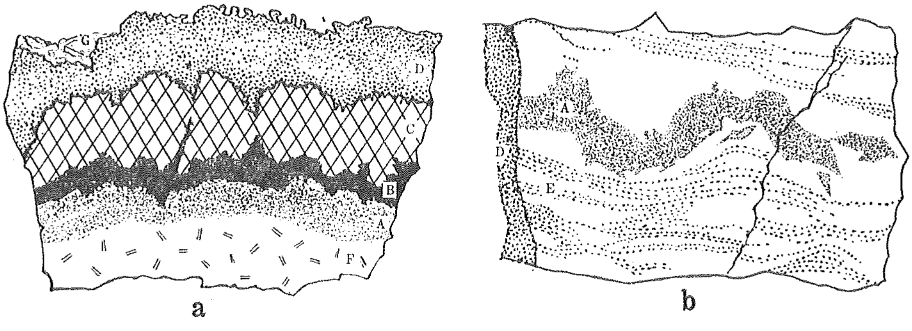


Fig. 4. Drawing of specimens of ore from the Ohkubo vein. $\frac{1}{2}\times$

a. Banded ore composing of different mineral.
A: cassiterite-tetradymite and stannite-famatinite,
B: chalcopyrite-pyrite, C: sphalerite-galena,
D: pyrite, F: wall rock, G: gypsum crystal.

b. Siliceous ore. Splitters consisting of cassiterite-tetradymite (A) are in light gray siliceous mass with pyrite laminations (E). Both are veined by pyrite veinlet of later stage.

vein shows violet gray siliceous mass with irregular patches of common sulphides or light gray siliceous mass with fine laminations of pyrite with sphalerite. It is remarkable that at some parts in the light gray siliceous mass, there are small irregular and xenolith-like splitters of violet gray blebs (Fig. 4, b).

*Cassiterite.* The peculiar feature of the mineralization in question is the occurrence of cassiterite, which mineral has not hitherto been known in SW-Hokkaidô; even the element of tin was very rare and only one species of mineral containing that element has been reported as colusite, tin bearing tetrahedrite, from a deposit.[(10)] Cassiterite occurs in dark gray compact siliceous salband and forms fine idiomorphic grain (0.01 mm) which is intermixed with fine quartz grain (0.1–0.5 mm), or is frequently enclosed with tetradymite and stannite. A few instances where cassiterite occurs from hydrothermal deposits in Japan are known such as at the Iwafune mine, Niigata Pref. or the Ikuno-Akenobe mines, Hyôgo Pref.,[(6)] but the mineral associates with such high temperature minerals as molybdenite, wolframite or topaz.

*Tetradymite* is found restrictedly in the dark gray siliceous band in close association with cassiterite, and without any other sulphides. The mineral shows fine irregular flake (0.1 mm long) composed of a few different orientated crystals, and fills among quartz grains (Pl. I, 2). Two modes of occurrence of tetradymite are reported from Japan. The first, such as at Ohya, Mano, and Sawada, Miyagi Pref.[(17)] and Kinkei, Nagano Pref.,[(16)] these deposits are known as hypothermal (intrusive hydrothermal) gold quartz veins. The second are the epithermal (extrusive hydrothermal) gold tellurium quartz veins of Tertiary age, such as at Susaki, and Kawazu (Rendaiji), Shizuoka Pref.[(8)] and at Mutsu, Aomori Pref.[(5)].

To the naked eye, the zone of cassiterite-tetradymite gradually grades into the next zone of stannite-famatinite-chalcopyrite, but under the microscope there are distinct discontinuous layers which consist of feathery or short columnar quartz with much inclusion of sericite. The other discontinuities are very distinct between the zone of cassiterite-tetradymite or famatinite-stannite-chalcopyrite and that of common sulphide minerals (Pl. I, 1). The intimate association of cassiterite and tetradymite in this deposit seems to be closely connected to a higher temperature mineralization.

*Stannite* occurs from the inner part of violet gray cassiterite bearing quartz mass or band. It associates almost always with chalcopyrite, or famatinite and tetrahedrite, and often with cassiterite replacing pyrite (Pl. I, 3). The mineral is very irregular grain being composed of mosaic aggregate of finer grains (0.015 mm).

*Famatinite* is irregular grain of pale persimmon color (0.01 mm), and has intimate intergrowth with stannite, chalcopyrite and tetrahedrite (Pl. I, 5 and 6), and often shows graphic intergrowth with chalcopyrite along its margin (Pl. I, 4). The mineral shows complex "Verzahnt" structure under the crossed nicols.

*Chalcopyrite* and *Tetrahedrite.* Chalcopyrite is small irregular grain forming the intergrowth with stannite or famatinite, and often includes tetrahedrite and bismuthinite. Chalcopyrite occurs sometimes as irregular larger masses or patches; such chalcopyrite shows distinct anisotropism and lamellar twinnings (Pl. I, 7). Tetrahedrite associates with stannite, famatinite and chalcopyrite, and especially replaces chalcopyrite from its margin.

*Bismuthinite* occurs as small flakes (0.2 mm) and is always enclosed with chalcopyrite or sometimes with famatinite-stannite intergrowth (Pl. I, 7).

*Luzonite* is determined by T. MIYAKE from only one ore specimen.[11] The mineral is enclosed with chalcopyrite and associated with tetrahedrite. Under the microscope luzonite is easily recognized on account of its pinkish gray color, distinct anisotropism and multiple twinnings. The present writer has not yet observed this mineral in any specimen.

*Pyrite* and *Sphalerite.* Considerable amount of fine grained idiomorphic or hypidiomorphic pyrite (0.3 mm) scattered in the siliceous mass. Yet it coexists with other ore minerals, and such pyrite seems to occur independently from others except stannite. Often granular pyrite takes thin parallel lamination or curious radial form.

Sometimes massive pyrite patches with sphalerite and chalcopyrite are also found in the quartz mass. But generally sphalerite is poor in the quartz mass and it occurs sporadically with pyrite.

A few gray and graysh white scaly minerals are found in the ore sporadically; they seem to be silver bearing minerals but are not yet determined. A fine *gold* grain has been observed near the tetradymite in one polished section.

The association and mode of occurrence of aforementioned minerals seem to give a characteristic feature to the Ohkubo vein differentiating it from the principal vein and the other subsidiary veins. The mutual relations existing among those minerals and the texture of siliceous ore would render following definite sets of minerals.

Sn-Te-Bi-Sb-(Cu) Mineralization

I Cassiterite-tetradymite

II (a) Cassiterite-chalcopyrite-stannite-pyrite

(b) Stannite-famatinite-tetrahedrite-chalcopyrite-bismuthinite

(c) Luzonite-chalcopyrite-tetrahedrite

(d) Pyrite-sphalerite

Sulphide rich bands of the Ohkubo vein consist of pyrite, sphalerite, chalcopyrite and galena with gangues of quartz, Mn-calcite, barite, gypsum and clay minerals. The properties of each of those minerals, their mode of occurrence and mutual relations among them are entirely the same as the banded ores of the principal vein and other subsidiary sulphide veins. The common sulphide paragenesis found in the Ohkubo vein is also without doubt the lower temperature formation of $FeS_2$-Pb-Zn-(Cu) mineralization.

A question of primary importance is whether the Ohkubo vein is different from the principal vein in origin or not. This question may be answered in the negative and that for several reasons.

The Ohkubo vein runs parallel to the principal vein at No. 5 sub-level (80 m level) and No. 5 level (85 m level). However at upper No. 4 level (70 m level) and lower No. 6 level (100 m level) there is not any vein which has characteristic features like the siliceous Ohkubo vein, but several veins which are rich in sulphide similar to the principal vein. Cassiterite is found in a few sections from some parts of the principal vein and its branches at western portion on No. 6 level, and at eastern portions on No. 4 level and on No. 8 level (130 m level). Minute grains of stannite, famatitite with chalcopyrite are found as inclusions in sphalerite from the Ohkubo vein, but also at any part of the principal vein and others.

The Ohkubo vein, principal vein and other sulphide veins or branches seem to occupy the equal position and to display quite the same constitution of networks in a fracture zone. We have already known many instances where there were complex telescoping of minerals or temporal facies changes in a mineral-deposit.

It is assumed that the vein-forming process was probably rather short in duration of time, but various surges of solution ascended in a fracture zone continuously. Cassiterite perhaps crystallized from the first surge of ascending solution while on the way of its course, and settled with tetradymite along the surface of fissures. Crystallization and deposition of the intergrowths of famatinite, stannite, chalcopyrite, bismuthinite and tetrahedrite then followed. Stannite deposited as a reaction product between cassiterite or pyrite and the ore solution.[4] These mineralizations gave a conspicuous feature to the vein, but continuously at this same horizon common sulphide minerals crystallized and deposited in the new and old fissures from the next surges of ore solution. Moreover, obviously the ascending surges of sulphide bearing solution have been repeated, then consequently the overlaping of some sulphides such as pyrite, sphalerite and chalcopyrite might be produced.

## Summary


The country rocks of the Suttsu deposit belong to the Miocene green tuff series. Veins show complex hummock structure, and every one is of composite vein type.

The ore consists generally of pyrite, spalerite and galena, but is very poor in chalcopyrite and other Cu-minerals. The gangue minerals are quartz, Mn-calcite, barite, gypsum and clay-minerals. The deposit has been considered as a vein type of "black ore deposits".

Recently a siliceous vein containing famatinite, stannite and tetrahedrite has been found in the western portion on No. 5 sublevel and then cassiterite, tetradymite and bismuthinte are also discovered in the same vein. This vein, called Ohkubo vein, runs nearly parallel to the principal vein, but may be a branch of the latter.

It may be considered that there are two stages of mineralizations; the first Sn-Te-Bi-Sb-(Cu) mineralization and the second$FeS_2$-Pb-Zn-(Cu) mineralization. The first mineralization occurs at earlier stage, but depositions are so feeble that they possess only scientific interest. The second mineralization represents a later formation, and depositions are rather intense with the result that they possess economic importance.

As far as the present author is aware, there is no other instance known in which cassiterite is found in close association with lower temperature black ore deposits of Hokkaidô or the inner zone of NE-Japan.

These two mineralizations at the Suttsu mine do not belong to the different stages, but have taken place continuously. Moreover the later mineralization is repeated. An assumption may be admitted for such a deposit that the surrounding area has been effected by the xenothermal or subvolcanic condition.

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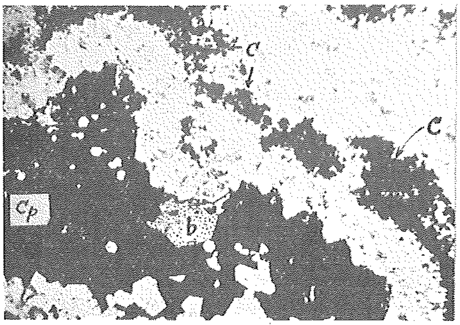
Plate I

## Plate I

1. Chalcopyrite, barite and cassiterite.
   Banded ore consisting of layer of chalcopyrite (cp. black) with barite (b. mottled gray) and that of cassiterite (c. fine granular).
   × 30. 1 Nic., thin section (No. s-1163)
2. Cassiterite and tetradymite.
   Cassiterite (c. light gray) and tetradymite (t. white).
   × 80. 1 Nic., polished section (No. p-1043)
3. Pyrite, stannite and famatinite.
   Pyrite (py. white) replaced by stannite (st. darker gray) and famatinite (fm. lighter gray).
   × 100. 1 Nic., polished section (No. p-1069)
4. Stannite, famatinite and chalcopyrite.
   Graphic intergrowths of famatinite (fm. lighter gray) and chalcopyrite (cp. white) in stannite (st. gray).
   × 30. 1 Nic., polished section (No. p-841)
5. Tetrahedrite, famatinite and pyrite.
   Mutual growths of tetrahedrite (d. lighter gray) and famatinite (fm. darker gray), and pyrite (py. white).
   × 250. 1 Nic., polished section (No. p-1069)
6. Famatinite, stannite and bismuthinite.
   Mutual growths of famatinite (fm. darker gray) and stannite (st. lighter gray), and inclusions of bismuthinite (bs. white).
   × 250. 1 Nic., polished section (No. p-1061).
7. Bismuthinite and chalcopyrite.
   Lamellar twinnings of chalcopyrite (cp. gray) with inclusions of bismuthinite (bs. white). Etched with $KMnO_4+H_2SO_4$.
   × 80. 1Nic. polished section (No. p-732)
8. Pyrite and marcasite.
   Nuclei of marcasite (mc. gray and white) enclosed in pyrite grain (py. light gray).
   × 80. + Nic., polished section (No. p-1099)

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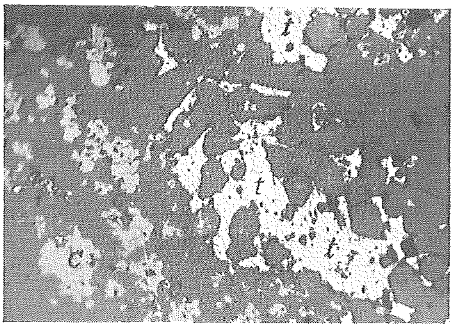


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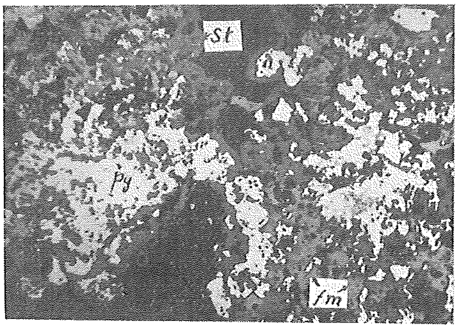


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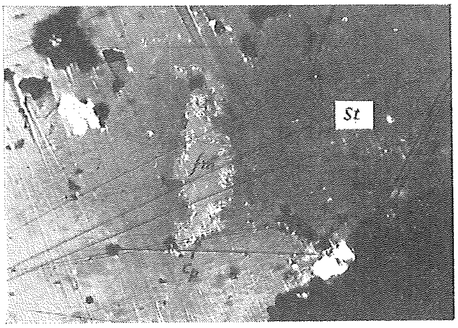


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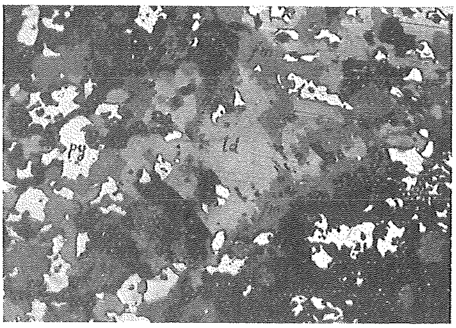


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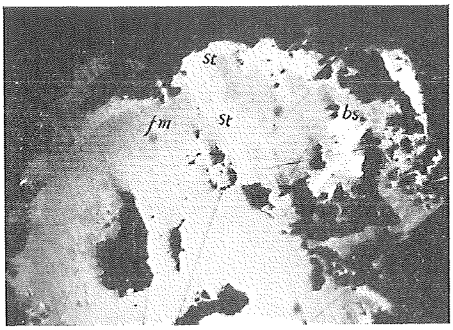


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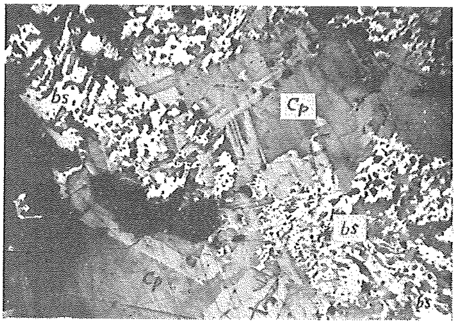


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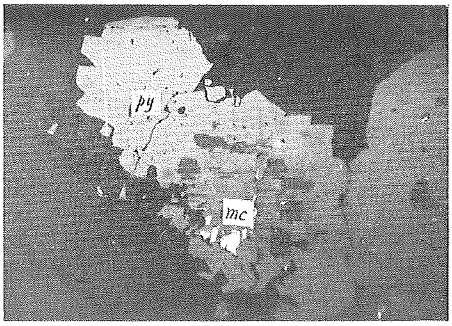


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M. Ishibashi: A Sn-Te-Bi-Sb Parageneis in ore from the Suttsu mine.