ON THE RELATION BETWEEN MASSIVE PYRITIC ORE DEPOSITS AND HYDROTHERMAL Cu-Pb-Zn-W VEINS IN THE AKENOBE MINE, JAPAN

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INTRODUCTION

Mineralizations of ores are the particular product of specific geologic processes, and are genetically classified into various types, each of which has a definite relationship to the magmatic or sedimentary phases of geotectonic evolution of the crustal regions. Series of ore deposits which were formed during certain geosynclinal-orogenic cycle tend to occur usually in a terrain that consists of contemporary geologic formations. Accordingly, ore deposits of different genetic types or different geologic ages of formation are generally distributed and located in different regions, but it seems also probable that in a rare case ore deposits of different types or ages happen occasionally to occur closely in one and the same area. Such rare case can be expected only in polycyclic, or polyorogenic, complicated mobile belts of the world.

Within the mining district of Akenobe mine do occur two types of ore deposits of different genetic types and ages, the one is subvolcanic-hydrothermal copper-lead-zinc-tin-tungsten quartz vein deposits of the Tertiary age, which are main object of mining, and the other is bedded massive, cupriferous pyritic or related ore deposits, as it is simply called "Kieslager", of probable Permo-Carboniferous age. During the course of mining operations undertaken hitherto in the mine, interesting relations between ore deposits of the two types mentioned above have been recognized in several localities, where the bedded pyritic deposits are intersected by the hydrothermal
vein deposits. It seems very noteworthy to describe the occurrences in some detail and to consider the mineralogical aspect of ores involved in these rare cases.

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GEOLOGIC SETTING OF ORE DEPOSITS

Outline of geology

In the Akenobe mining district underlie mainly Paleozoic sedimentary formations, gabbroic intrusive rocks, granophyric rocks and many kinds of dike rocks. The geology of the mine was recently published by Saigusa (1958) and Sekine (1959) in relation to mineralization, therefore the reader is recommended to refer to these papers. Brief outline of geology, however, should be mentioned here for understanding the basic circumstance of ore deposits under consideration.

As shown in the simplified geologic map of the eastern half of the mining district (Fig. 1), the Paleozoic sedimentary formations are composed, in general ascending order, of thick "green rock complex" including schalsteins, diabasic rocks and variolite basalt lavas, inserting chert bed, green tuffaceous argillites, gray and black argillites, and variegated phyllitic rocks. General strike of formations is N40–70°E, and dip northwesterly at 30°–80°, or southeasterly in the extreme southeastern part. These formations represent surely accumulations of the eugeosynclinal basin of the Permo-Carboniferous period of Japan.

Gabbroic intrusives occur in the sedimentary formations as large elongate masses, and stretch at the surface northeastward parallel to the regional structural trend, but they cut irregularly strata of the sedimentary formations in depth. The intrusive masses show strong facies variance ranging from basic uralite gabbro,
hornblende gabbro to hornblende diorite, and contain abundant schlierens and network dikelets of differentiated quartz diorite aplitic facies. They often show fine banded or gneissose structure and mylonitic, metagabbroic appearance. The surrounding sedimentary rocks as well as the intrusives suffer intense epidotization and chloritization, and also prehnitization especially within the intrusives. Petrographic characters and modes of occurrence as well as their relations to geologic structures suggest invariably that the intrusion of gabbroic rocks must have taken place synkinematically during the orogenic phase of the eugeosynclinal basin. Intrusions of gabbroic rocks seem to have played important role in the formation of phyllitic zones originating from variegated argillites, which are now situated predominantly in the hanging wall side of the intrusive masses.

Granophytic or granite porphyry stocks occur in the westernmost part of the mining district, not shown on Fig. 1, and they indicate no evidence suggesting definite age of intrusion, though they cut clearly the Paleozoic formations. They might belong to a part of the synorogenic acid intrusion.

Abundant dike rocks are felsite, hornblende porphyrite, garnet andesite, hornblende andesite, rhyolite and basalt. The former two occur mainly in northeast direction, while the rest in northwest. They belong generally to the Tertiary volcanic activity and cut across hydrothermal base metal veins in many places.

Outline of two types of ore deposits

It seems very remarkable that the two different types of ore
deposits occur closely together in the same mining area. They are bedded massive, cupriferous pyritic deposits and related deposits, and subvolcanic-hydrothermal vein deposits.

*Hydrothermal vein deposits.* The hydrothermal vein deposits have long been in operation and produced enormous amount of copper, lead, zinc, tin, tungsten and accompanying gold, silver, arsenic ore, and magnetite. These veins have been in many years a target of both economic and scientific interest, and have frequently been reported by Kato (1917, 1920, 1926), and recently by Saigusa (1958), Sekine (1959), Abe (1962) and many others.

Vein deposits occur rather regularly in sets of vein group which run parallel closely (Saigusa, 1958), and in the eastern half of the mining district they are arranged mainly in northwest direction and dip northeastward as well as southwestward in some cases, transversing the general structural trend of the area, as shown in Fig. 1.

Major ore minerals are, in order of decreasing importance, chalcopyrite, sphalerite, cassiterite, galena, bornite, wolframite, scheelite, arsenopyrite, magnetite, and subordinate amount of pyrrhotite, pyrite, bismuthinite, native bismuth, hematite, molybdenite, etc. The ores are associated with varying amounts of quartz, chalcedonic quartz, fluorite, calcite, siderite, chlorite, apatite, manganiferous calcite, and clay minerals. Various ores show significant phases of mineralization and remarkable structural and textural features, which suggest the formation of veins to be of subvolcanic magma origin, and also display remarkable zonal distribution of ores within vein groups as investigated by Abe (1962).

*Massive pyritic deposits* Regarding bedded massive, cupriferous pyritic deposits, champion ore bodies are the Minamidani deposits which are situated about some kilometers northeast from mine office. Reserves of the Minamidani pyritic ores have nearly come to an end, and large part of the subsurface workings are now almost inaccessible to investigation. Unfortunately the Minamidani deposits have not ever been described in detail, although there are many unpublished company-own data.

Pyritic ore deposits of Minamidani lie just in the phyllitic zone of argillitic facies of the Paleozoic formations, which are composed of green phyllites, siliceous phyllites, black phyllites, phyllitic or massive schalsteins. Ore bodies are stratigraphically bounded directly in green phyllite. These strata are intruded at the southern side of ore deposits by semi-buried, large intrusive masses
of gabbroic rocks, and also in several localities by hornblende porphyrite and hornblende andesite dikes of usually less than a few meter wide.

The ore deposits consisting of three major ore bodies and several subordinate small lenses occur almost concordantly to the stratification, and they are locally folded along small anticlines, and are often transected by abundant longitudinal, transversal, and oblique faults which separate the block of ore bodies wide apart, so that ore zones appear in imbricate structure and occur in stepwise dislocated fault blocks. General strike of ore zones runs N70°E and dips are 30–50° NW or SE. The ore zones have overall strike length of about 900m, width of about 100–150m, and thickness of 3 to 10m. It remains yet open to question that even major ore bodies, aside the small bodies in marginal portion, lie in the original same stratigraphic horizon. In the southwestern part of the ore zones, ore bodies bounded by faults become much smaller suggesting the original margin of ore deposition, while in the northeastern part, considerably promising ore bodies have recently been drilled even beyond the terminal large transversal fault.

Constituent minerals of the ores are mainly pyrite, chalcopyrite and a small amount of sphalerite and galena, associated with varying amount of quartz, chlorite, and carbonates. Massive quartzose layers of irregularly banded form with very scarce amount of ore minerals occur locally in the upper part of the flat-lying ore bodies.

Remarkable feature of the ore deposits is the development of mangetitic ore with patches of massive chalcopyrite which occurs in limited localities, especially in southwestern part of the ore zones. The mangetitic ore is relatively abundant in ore bodies of apparent lower horizon, in marginal thinning portion of the deposits, and along footwall side, and also in the vicinity along some of the large faults crossing the pyritic deposits. The mangetitic ores contain varying amounts of massive chalcopyrite in segregation form, and dissemination of pyrrhotite, and are intimately associated with abundant quartz, chlorite, ilvaite, and a small amount of actinolite. Nakano (1930) reported the presence of zone composed of garnet and diopside-hedenbergite, and zone of magnetite-pyrrhotite between wall rocks and pyritic ores, and he ascribed the zones to the thermal effect of high-temperature ore solutions originating in intruding gabbroic residual magma. It seems remarkable that the magnetite in these ores shows aggregate form of radial, blade-like shape. This feature will be referred again later in this paper.
RELATIONS BETWEEN ORE BODIES OF TWO DIFFERENT TYPES

Besides the Minamidani deposits of cupriferous pyritic ores, small lenticular ore bodies of same kind, or similar bedded deposits including magnetite-chalcopyrite or pyrrhotite ores have been found in several localities within the eastern half of the Akenobe mining district (Fig. 1). The localities are (1) Komori vein, 1L., Stope, (2) Nihonmatsu branch vein, Old Pit, (3) upstream of Shiraiwa valley, (4) Kamagatani vein, 10L., S17 Stope, and 12L., S18, (5) Shotoku vein, 12L., S19 Stope, and (6) Crosscut-600 F.L. to Kanakidani vein group. Further localities were suggested, but not ascertained.

Loc. 1, Komori vein
Small lenticular deposit of magnetite-chalcopyrite ore occurs concordantly in green and chloritized black phyllites and phyllitic schalstein having strike of N70–80°E and dip of 60–80°NW, and

Fig. 2. Komori vein and chalcopyrite-magnetite deposit.

Fig. 3. Nihonmatsu vein and magnetite deposit.
is obliquely intersected clearly by the banded quartz vein of copper-tin ore (Fig. 2). The lenticular deposit is bedded form of up to 50cm thick and more than several meters long, and is composed of three bands, magnetite-siderite-quartz band being the upper and the lower bands and massive chalcopyrite band in the middle. A row of angular breccias of disrupted ores is introduced amidst the copper-tin quartz vein, and arrangement of breccias suggests the relative displacement of separated segments of magnetite-chalcopyrite deposit.

Loc. 2 Nihonmatsu vein Concordant magnetite-quartz lens, very similar to the one mentioned above, occurs in the transitional zone between black and green phyllites, and is cut across at right angle by the vein fissure of copper-zinc-tin quartz ore (Fig. 3). The lenticular deposit has a thickness of about 60 cm and extends more than 17 m in strike direction. The Nihonmatsu vein is separated from the magnetite ore by intervening thin shear zone of altered rocks. The magnetite-quartz ore is macroscopically disseminated and veined irregularly by chalcopyrite of almost invisible size.

Geologic structure suggests the occurrences these two localities to be in same stratigraphic horizon, and the distance between these localities and nearby intruding gabbro seems to be not more than 30 meters in underground.

Loc. 3, Shiraiwa valley Small ore bodies of massive pyritic ore of ordinary type occur in massive schalstein underlying the chloritized, laminated schalstein. The ore bodies are up to 50 cm in thickness and extend intermittently for several meters. They expose on river bed and slope.

Loc. 4, Kamagatani vein Cupriferous pyritic bed averaging 1m thick with interstratified thin layers of siliceous gray argillite occurs in phyllitic schalstein dipping gently toward north, and is cut across clearly by Kamagatani vein of up to 1.5 m wide striking N 70°W and dipping 70°NE, which consists of chalcopyrite, sphalerite, calcite and quartz. In the very vicinity of the transverse the pyritic ore bed is disrupted and fractured by calcite-quartz veinlets. Slender solution cavities representing fissures are also recognized. The pyritic bed contains frequently thin layers of chalcopyrite and considerable amount of sphalerite, and is associated also with thin seams of red hematitic chert.

Loc. 5, Shotoku vein Massive pyritic ore of bedded form up to 30cm thick is cut and fractured by base metal-fluorite-calcite-quartz vein of Shotoku and its related veinlets. Several breccias of disrupted pyritic ore are enclosed within the vein and vein fissure
Three cases mentioned just above suggest the development of pyritic ore bed within the same stratigraphic horizon.

*Loc. 6, Crosscut-600 F.L.* Pyrite-bearing pyrrhotite ore with considerable amount of sphalerite occurs in dark green chloritic phyllite. It shows an outline of layered form striking N40°E and dipping 20–45°NW. The thickness amounts up to 1 m, but its extension is not explored. Massive pyrrhotite ore is restricted only to the topmost part of the layer, and the rest of the deposit shows irregular but somewhat layered network of pyrrhotite-sphalerite seams and veinlets in chloritic phyllite, and the mineralization decreases
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downward and diminishes rather abruptly. Boundaries between
the ore and phyllite are irregular and not smooth, and phyllite is
often mineralized by irregular veinlets of the ore. A remarkable
feature of the ore is the large grain size of constituent sulphide minerals
as compared with ordinary massive pyritic ores, massive pyrrhotite
ore contains scattered grains, aggregates and patches of pyrite,
sphalerite, and chlorite often up to 1 cm across, and shows only
vague banded structure of ore. Sometimes the ore accompanies small
amount of chalcopyrite and marcasite in close connection with
pyrite aggregates.

Microscopic Feature of Ores at the Intersection

Mineralogical features seem at first sight to point the classifica-
tion of the ores of occurrences mentioned just above into three
groups: pyritic, pyrrhotitic, and magnetitic-chalcopyritic ores.
Besides these, the Minamidani deposits contain also all kinds of ores
corresponding to these three groups. Microscopic observations
may visualize some interesting relations among these groups.

Pyritic ores

So far as pyritic ores concerned, their mineralogical features lie
within the range of ordinary massive, cupriferous pyritic deposits of
familiar type. Pyrite being euhedral, subhedral, irregular, fractured
or rounded grains and aggregates are cemented in, replaced or veined
by varying amount of chalcopyrite, sphalerite, galena and quartz
(Fig. 5A, 5B and 5C). Grain size of pyrite varies widely from 0.01 to
0.05 mm and shows often heterogeneous distribution. Colloidal
form of pyrite has not been found.

In the pyritic ores, neither pyrrhotite, marcasite nor bornite is
commonly found. Euhedral grains of arsenopyrite are present in
cases where pyritic ores are permeated by hydrothermal vein quartz
as at Kamagatani, and are found in infiltrating gangue quartz and
calcite. At Kamagatani, magnetite is rarely found having only relict
form of unknown origin (Fig. 5C). Mineral paragenesis and textural
features do not show any remarkable effect of the later hydrothermal
alteration by Kamagatani vein on the original mineralogical
assemblage of pyritic ores.

Pyrrhotitic ores

Lenticular mass of pyrrhotite in the Crosscut–600 F.L. contains
considerable amount of sphalerite patches. Pyrite is localized in
granular aggregates, along whose marginal part occur irregular aggregates of marcasite of somewhat porous texture. Pyrite and marcasite are often associated with irregular forms of chalcopyrite. Sphalerite contains semi-oriented intergrowth of abundant blebs and veinlets of pyrrhotite and chalcopyrite (Fig. 6A). Intergrown blebs of pyrrhotite are larger in grain and veinlet size than those of chalcopyrite. The ore is associated with small amount of galena, but no magnetite is found in the ore. Texture and mineral assemblage suggest that the pyrrhotitic ore must have been converted from pyritic ore by the thermal effect of nearby intruding gabbroic magma.

Pyrrhotite ores found in Minamidani deposits contain considerable amount of magnetite, sphalerite, galena, quartz, and ilvaite. Magnetite is of anhedral or irregular form, and is replaced by galena that crystallized later. Blebs of chalcopyrite and pyrrhotite are restricted only within area of sphalerite. Sphalerite grains are often

B. Massive pyritic ore, Kamagatani. Anhedral pyrite grains (white) are embedded in sphalerite (dark gray) and chalcopyrite (light gray). Chalcopyrite veins sphalerite, and cements pyrite. Quartz (black).
C. Fragment of pyritic ore cemented by Kamagatani vein. Scarce pyrite, (white, with relief) is distributed in chalcopyrite (light gray) that veins and replaces sphalerite (dark gray, flat), and magnetite (dark gray, with relief, at center and right). (x 80)
D. Magnetite ore, Minamidani. Radiating blades of magnetite (light gray) embedded in quartz (dark gray). Presence of fine blebs of chalcopyrite (white) is restricted only to ilvaite area (large, gray grain at center and left). (x 80)
E. Magnetite-chalcopyrite ore, Minamidani. Bundles of slender magnetite (gray) and chalcopyrite (white with sphalerite blebs) are embedded in ilvaite (shades of dark gray). (x 80)
F. Chalcopyrite patch in magnetite ore, Minamidani. Magnetite (gray) aggregate with quartz and ilvaite (dark gray) and isolated grains are cemented and replaced by chalcopyrite (white) with sphalerite blebs. (x 80)
G. Pyrrhotite ore, Minamidani. Irregular magnetite grains (gray) contain galena (white at right) and chalcopyrite (white at left). Sphalerite (gray) with abundant blebs of chalcopyrite and pyrrhotite is surrounded by magnetite rim. Gangue is aggregate of chlorite, epidote and carbonate. (x 80)
H. Pyrrhotite ore, Minamidani. Galena (light gray at center) replaces magnetite (gray). Pyrrhotite (gray, at right) and sphalerite (gray) with abundant pyrrhotite blebs are separated from galena by magnetite. Gangue (black). (x 80)
Fig. 5. Photomicrographs of ores.

A. Massive pyritic ore, Kamagatani. Pyrite (white) of various shape and grain size is embedded in chalcopyrite (light gray), sphalerite (dark gray) and some quartz (black). (×80)
Fig. 6. Photomicrographs of ores.
A. Massive pyrrhotite ore, Crosscut-600 F.L. Semi-oriented intergrowth of pyrrhotite and chalcopyrite blebs (both in light gray) in sphalerite (gray matrix) which is a patch in massive pyrrhotite. ($\times 80$)
B. Magnetite ore, Nihonmatsu. Magnetite (light gray) of irregular,
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surrounded by magnetite rim (Fig. 5G and 5H). Pyrite is very rare in the pyrrhotite ores.

*Magnetite-chalcopyritic ores*

Ores of this kind are represented by those of Komori and Nihonmatsu, and also occur in considerable amount in the restricted part of Minamidani deposits.

As mentioned previously, the massive chalcopyrite ore forms a middle band sandwiched by magnetite bands in Komori, but in Nihonmatsu chalcopyrite is only fine dissemination. In the Minamidani deposits, however, chalcopyrite occur in irregular patches and masses in magnetite ore.

Magnetite at Nihonmatsu shows aggregate of very finegrained magnetite and siderite, and the aggregate is arranged rather in dendritic or radial structure, and is embedded in gangue quartz (Fig. 6B). Small irregular grains of chalcopyrite and pyrrhotite occur in quartz. Bornite seems to occur only in vicinity of intersecting vein. No pyrite is found.

Magnetite of Komori has a similar feature to that of Nihonmatsu. Anhedral, irregular grains of magnetite up to 0.03mm across cemented by interstitial siderite are embedded in quartz and calcite, and
these magnetite-siderite aggregates show coagulating form suggesting colloidal origin of syneresis texture (Fig. 6C and 6D). Transformation of siderite to magnetite seems very possible, as discussed previously on the magnetite of hydrothermal veins of Akenobe (Sekine, 1959). Marginal grains of magnetite-siderite aggregates show often euhedral shape against gangue quartz (Fig. 6C). In the magnetite bands, chalcopyrite is present in a very small amount, usually embedded in quartz, but sometimes fills and replaces directly the magnetite (Fig. 6D, 6E and 6F). Bornite occurs in quartz as separate grains or combined with chalcopyrite, as if bornite occupies otherwise chalcopyrite area. Sphalerite with blebs of chalcopyrite is sometimes found, but galena is very rare.

In the transitional portion between magnetite and chalcopyrite band, interfingering areas of magnetite or chalcopyrite of several millimeter across protrude each other, as they suggest the squeezing movement of fluidal materials. Quartz is always more abundant in magnetite band than in chalcopyrite band. Magnetite becomes granular and massive in chalcopyrite band, and is surrounded by intervening siderite-chlorite rims against chalcopyrite (Fig. 6F). No pyrrhotite and only rare pyrite are found in magnetite bands, but small amount of these minerals occur in chalcopyrite band. Pyrite in chalcopyrite area shows often corroded form, and pyrrhotite shows sporadic occurrence of irregular shape in chalcopyrite. Euhedral grains and aggregates of flaky chlorite are enclosed in chalcopyrite. Sphalerite is always a subordinate accompaniment having mutual boundary in chalcopyrite (Fig. 6G). Bornite is very rarely found in chalcopyrite band.

Chalcopyrite-bearing magnetite ores of Minamidani deposits are remarkable in their occurrences as mentioned in earlier chapter. Magnetite of the ores occurs as forms of radiating bundle, slender blade, or elongate aggregate in quartz and ilvaite (Fig. 5D, 5E and 5F). Although magnetite aggregates display remarkable similarity in forms to those of magnetitic ores in the other localities, aggregates in this case do not include the interstitial siderite. Some amounts of epidote, actinolite and chlorite may also be present. Ilvaite contains abundant tiny grains of chalcopyrite, pyrrhotite, or galena, and rare cube pyrite (Fig. 5D). Pyrrhotite occurs sometimes in chalcopyrite area as grains up to 0.1 mm across.

* Magnetitic ore breccias enclosed in hydrothermal vein*

At the intersection of two types of ore deposits, ore breccias
of the bedded type may be expected as inclusion in hydrothermal veins. Pyritic ore breccias were not available for our scrutiny, therefore only magnetitic ore breccias of the Komori vein were used for microscopic observation.

Magnetitic ore breccias are enclosed in and permeated with quartz and calcite gangues containing tin-copper ore. Magnetite-siderite aggregates remain almost unchanged by the hydrothermal solution, however, sometimes becoming loosely, in gangue quartz and calcite, and in bornite (Fig. 6H). The most significant feature of the breccias is the presence of abundant bornite in comparison with original magnetitic ores. The bornite occurs as grain and area in gangues and between magnetite-siderite aggregates, and is often fringed or veined by chalcopyrite, but lamellar chalcopyrite is sometimes arranged in bornite. Some of the bornite grains contain covellite having mutual boundary independently of chalcopyrite. Sphalerite containing often chalcopyrite blebs has a mutual boundary with bornite. No pyrrhotite and very rare pyrite are found in quartz cementing magnetite and bornite. Fine grain of stannite-like mineral is not yet identified. Cassiterite and apatite are disseminated in the breccias. Epidote and chlorite are also present in small amount. Magnetitic ores adjacent to hydrothermal vein show same mineralogical features, but the alteration halo seems very narrow.

**Consideration and Conclusion**

In recent years, some genetic considerations on pyrrhotite and magnetite ores which occur in close relation to pyritic ore deposits were given to the deposits of Yanahara mine by Hayase and Mariko, Higashimoto, and Tsusue. According to the stability relation and variation in magnetic susceptibility of pyrrhotite and estimation of heat conduction around intrusive bodies, Hayase and Mariko (1961) concluded that the formation of pyrrhotite and magnetite ores should be ascribed to the dissociation of pyrite which was effectuated by the thermal metamorphism of intruding quartz porphyry and underlying batholith. They found magnetite pseudomorph of short prismatic or platy form after pyrrhotite. Higashimoto (1958, 1962), however, thought that the pyrrhotite and magnetite, except those adjacent directly to quartz porphyry dike, were formed not by thermal metamorphism of pyrite, but by the reaction of pyrite with hydrothermal solution, partly gaseous, of high temperature which was migrated from underlying granitic
batholith. In this case the consideration was mainly based on paragenetic relations and spectrochemical correlation of the ores. It should be considered that the pyrrhotite and magnetite of Yanahara mine occur in three modes of occurrence: the first, in pyrrhotite-magnetite zone occupying the lower margin of the pyritic deposits; the second, in irregular veinlets of pyrrhotite, magnetite and biotite within the pyritic deposits, which sometimes continue to the zone of the first case; and the last, in pyrrhotite and magnetite zones adjacent to quartz porphyry dikes. Tsusue (1962) estimated the temperature of formation of pyrrhotite based on the compositional variation of pyrrhotite by means of X-ray diffractometry, and case to the conclusion similar to that of Higashimoto. He ascribed the formation of magnetite and pyrrhotite in the first case to the diffusion of sulphur and oxygen without substantial participation of ascending fluid, and the formation of pyrrhotite veinlets to the interaction of pyritic ores with ascending fluid which was caused by the thermal metamorphic action of quartz diorite intrusion, while these minerals adjacent to quartz porphyry dikes were formed in situ by dissociation of pyrite.

With regard to pyrrhotitic and magnetitic ores of the lenticular or bedded-form deposits in Akenobe mine under consideration, the following conclusions seem to be derived in consideration of geologic structure, modes of occurrence, and paragenetic relations as described in previous chapters.

(1) Pyrrhotitic ores of the Crosscut-600 F.L. to Kanakidani indicate the possibility that they were formed from cupriferous pyritic ore by thermal metamorphic action of nearby intruding gabbro stocks, partly at least by interaction with fluid or by mobilization of pre-existing pyritic ore.

(2) Pyrrhotitic and magnetitic ores of the Minamidani pyritic deposits may also be formed by interaction of pyritic ores with high-temperature fluid, that derived from intruding gabbro, ascending through major faults and rock boundaries.

(3) Magnetitic ores with chalcopyrite of Komori and Nihonmatsu show peculiar features of magnetite-siderite aggregate, and these magnetitic ores can not be explained reasonably by the thermal dissociation of pyrite and pyrrhotite or interaction with fluid, but suggest the primary formation of magnetite and siderite in aggregate in special depositional environment, previously to the time of gabbro intrusion. There remains, however, a possibility that the magnetite might be formed by the oxidation of siderite which was
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effected by the interaction with ascending fluid or by thermal action of intrusive gabbro.

(4) With regard to the later hydrothermal alteration of cupriferous pyritic ores of Kamagatani and Shotoku, where the ores are cut across by the vein, there has been found little change of minerals or paragenesis of pyritic ores, except some newly deposited vein stuffs.

(5) It should be mentioned, however, that the magnetitic-chalcopyritic ore breccias enclosed in Komori vein contain abundant bornite together with some covellite, without noticeable amount of pyrite and pyrrhotite. Magnetite-siderite aggregates remain unchanged in original texture, and no evidence is found that any part of magnetite or pyrrhotite, even bornite was formed by dissociation of pyrite or chalcopyrite. Bornite shows textural relation suggesting earlier formation than chalcopyrite. However, in the very vicinity of the breccias, the hydrothermal vein itself contains only a little amount of chalcopyrite, bornite or other sulphides, accordingly bornite and covellite of the breccias must have been deposited by the interaction of bornite-free magnetitic-chalcopyritic breccias with hydrothermal ore solutions. The resultant mineral association seems to suggest the alkaline nature of the hydrothermal ore solution.

(6) Thermal decomposition of minerals in the pyritic or related ores depends on the temperature and total heat supplied by the hydrothermal ore solution. The temperature of formation of the hydrothermal veins in Akenobe mine have been estimated to be in temperature range up to hypothermal condition by means of decrepitation method. As heat reservoir the hypo- to mesothermal ore solution is hardly able to warrant the thermal transformation, and much higher temperature is required. Heat capacity and latent heat of crystallization of ore solutions may be too small, so that the veins can not be the sufficient heat storage. Furthermore, longer duration of flowage of the hydrothermal ore solution may also be indispensable for influencing thermally the paragenesis of the massive pyritic ores.

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明延鉱山における含銅黃鉄鉱鉱床と熱水性銅鉛亜鉛錫
タングステン鉱脈との関係

摘　　要

南谷の層状含銅黄鉄鉱鉱床の下盤階・断層に沿う磁鉄鉱・硫鐵鉱鉱石が産する。鍼ケ谷10坑・12坑、鍼ヶ谷24坑、白谷上流の含銅黄鉄鉱鉱層は銅亜鉛鉱鉱床に切られ、金木谷向600尺流には層状含亜鉛硫鐵鉱鉱床が産出し、銅鉱1坑・二本松坑旧坑では層状含銅硫鉱鉱鉱床が銅鉱鉱脈に切られている。地質条件と鉱石の鉱物共生関係から、南谷・金木谷の場合は、銅鉱鉱鉱鉱石と銅鉱鉱脈に由来する高温流動体との反応で形成され、銅鉱・二本松の硫鉱鉱は銅鉱鉱と密接に共生し硫鉱鉱の形成は硫鉱鉱脈の銅鉱鉱鉱床への作用ではない。含銅黄鉄鉱鉱鉱石は熱水鉱液による著しい変化を受けていない。銅鉱1坑の文脈部では硫鉱鉱鉱鉱鉱石と鉱液の反応により、銅鉱鉱・銅鉱鉱鉱鉱石が形成され、銅鉱鉱・銅鉱鉱鉱鉱鉱床を鉱染している。