Copper-bearing Contact Deposits of Hua-tung-kou, Fu Hsien, Feng-tien Province, Manchuria

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1. Introduction

It is said that a gold placer mine at Hua-tung-kou was first worked about 700 years ago. However, there are no details on mining in this area until 1935. At this time, a Japanese textile manufacturer, Giheita HITOMI of Feng-tien tried to obtain low phosphorous pig iron from the ore of the Hua-tung-kou mine, using a small blast furnace and charcoal, after failing to operate a gold placer deposit there.

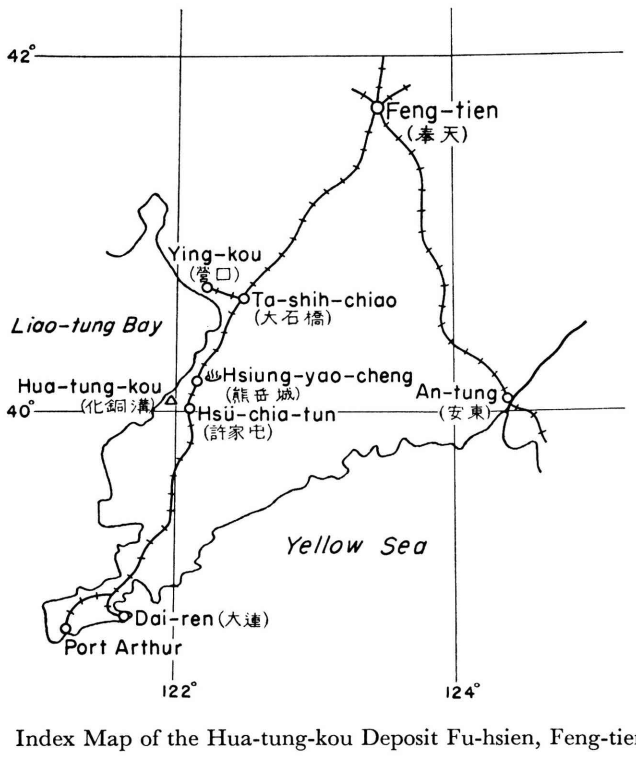

Fig. 1. Index Map of the Hua-tung-kou Deposit Fu-hsien, Feng-tien Prov.

In 1941 when HITOMI gave up the iron business and began exploration for copper ore, the present author surveyed the mine area and published a preliminary report[3] on the mode of occurrence of ludwigite. This borate mineral was found for the first time as one of the skarn minerals in the contact zone at this mine.

Based on this report, Masao ISHIBASHI carried out a detailed survey of the contact deposits in August 1942 and published two reports.[1,2] At the time of the investigation by the present author, the average grade of the copper ore of this mine was about 0.6% Cu, but as exploration proceeded it was found that the ore reserves were unexpectedly large, so that the Manchurian Mining Development Company decided to exploit the contact deposits under the name of the Hua-tung Mine in September 1942.

In 1944, the author carried out a more detailed investigation of the deposits. This paper is a report on that investigation, supplemented by ISHIBASHI's reports with his approval.

2. Location of the Mine

The Hua-tung Mine is located 15 km west of Hsu-chia-tun Station, which is 15 km south of Hsiung-yao-cheng Station on the railway between Dairen (Talien) and Feng-tien. The road between Hsu-chia-tun and the mine is good enough for trucks to transport concentrate and goods.

3. Geology

The basement of the mine area is composed of Pre-Cambrian sedimentary rocks intruded by granodiorite. Along the contact between the two, thermally metamorphosed rocks containing contact deposits accompanied by skarns are found. Gold placer deposits occur in alluvial sediment along the streams, and were worked in the past.

A. Sedimentary rock

Sedimentary rocks consist of dolomite and hornblende schist of pre-Sinian age, and Sinian quartzite unconformably covering the former.

Dolomite occupies the lowermost layer of the sedimentary rock, and grades upward into hornblende schist. Its lower limit can not be determined because of intruding granodiorite. An average of four analyses[4] shows that the dolomite contains 29 to 30% CaO and 18 to 21% MgO. The rock is partially altered to hornfels where the facies is sandy or argillaceous. The thickness of the dolomite is 380 m or more, and it is assigned to the Ta-shi-chiao series of the Liao-ho system according to Rinji SAITO.[5]

The hornblende schist occurs as a monoclinal formation dipping to the north. At Pei-tai-shan, it is covered by quartzite. Lithologically it is a green hornblende-oligoclase schist, locally intercalated with thin lenticular limestone. Although its

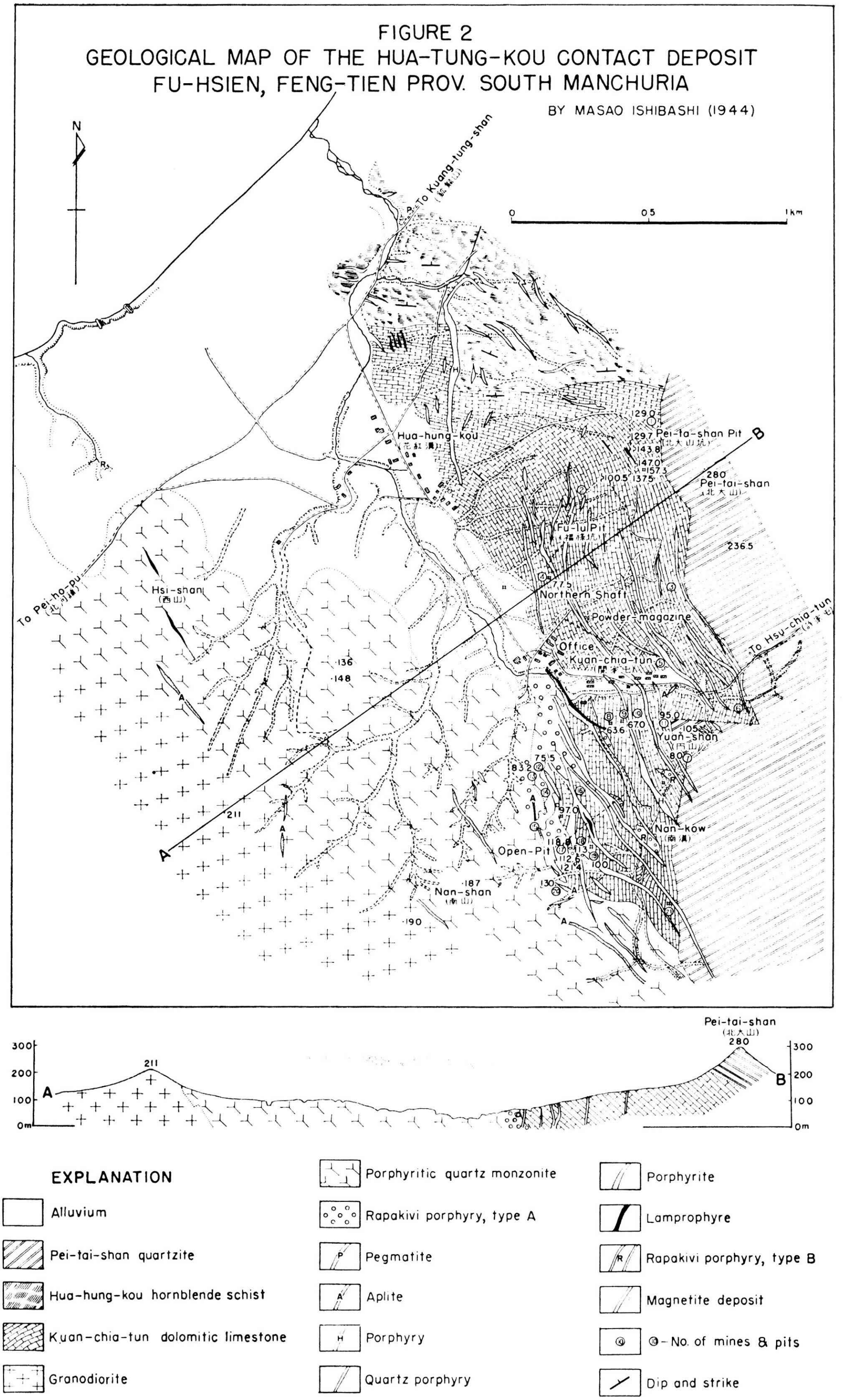
FIGURE 2
GEOLOGICAL MAP OF THE HUA-TUNG-KOU CONTACT DEPOSIT
FU-HSIEN, FENG-TIEN PROV. SOUTH MANCHURIA
BY MASAO ISHIBASHI (1944)
N
0
0.5
1km
To Kuang-tung-shan
Hua-hung-kou
Pei-ta-shan Pit
Pei-tai-shan
Fu-lu Pit
Hsi-shan
To Pei-ho-pu
Northern Shaft
Powder-magazine
Office
Kuan-chia-tun
To Hsu-chia-tun
Yuan-shan
Nan-kow
Open-Pit
Nan-shan
A
B
211
280
EXPLANATION
Alluvium
Pei-tai-shan quartzite
Hua-hung-kou hornblende schist
Kuan-chia-tun dolomitic limestone
Granodiorite
Porphyritic quartz monzonite
Rapakivi porphyry, type A
Pegmatite
Aplite
Porphyry
Quartz porphyry
Porphyrite
Lamprophyre
Rapakivi porphyry, type B
Magnetite deposit
No. of mines & pits
Dip and strike

Fig. 2

upper limit cannot be determined, the thickness of the schist must exceed 400 m.

The Sinian quarzite consists of light brown to grey-white quartzite in the lower part, and reddish-purple sandstone, intercalated with fine-grained conglomerate, in the upper part. The Sinian quartzite is thought to correspond to the Yung-ning sandstone that is well developed in the vicinity of Fu-chou.[5] The thickness exceeds 600 m, and the age is Upper Sinian.

B. Igneous rocks[2]

The granodiorite constituting Mt. Nan-shan is a stock which intrudes the dolomite. From the stock, numerous small dikes branch off. The granodiorite,* where it comes in contact with the dolomite, has changed into porphyritic quartz monzonite, part of which forms lingulate dikes having a rapakivi texture. There is no conclusive evidence available on the age of the granodiorite, but it is certain at least that intrusion took place after the Sinian quartzite had been deposited. Since the rock is characteristically alkalic, similar to Chien-shan granite, and shows no cataclastic effects, it is most likely that intrusion occurred during the Mesozoic era. Many of the dikes are highly acidic, and are distributed roughly parallel to the edge of the stock.

a. Granodiorite

The rock has a dosemic microporphyritic texture. The principal constituents are plagioclase (An_{40} in the core and An_{10} around the edge), microperthite, quartz, biotite and hornblende, with such accessory minerals as apatite, zircon, allanite, titanite and iron ore. The chemical composition (%) is as follows (analyst, Hiroshi HAMAGUCHI):

SiO_2, 69.58; TiO, 0.43; Al_2O_3, 15.07; Fe_2O_3, 0.74; FeO, 2.49; MgO, 1.09; CaO, 2.20; Na_2O, 3.70; K_2O, 4.52; P_2O_5, 0.24; H_2O, 0.33; total 100.39.

b. Porphyritic quartz monzonite

The rock is characterized by thick tabular phenocrysts of microperthite, 1 to 2 cm in diameter, which amount to about 15 crystals per 10 cm^2. The part in contact with the dolomite and lingulate portions of dikes are found to grade into rapakivi porphyry having phenocrysts mantled with oligoclase. The texture of the monzonite is dopatic porphyritic and the principal constituents are orthoclase, plagioclase (An_{34} in the core, An_{16} around the edge), quartz, green hornblende and biotite; accessory minerals are titanite, apatite, allanite, augite, zircon, etc. The chemical composition (%) is as follows:

SiO_2, 68.19; TiO_2, 0.41; Al_2O_3, 16.02; Fe_2O_3, 1.34; FeO, 1.07; MgO, 1.11; CaO, 4.10; Na_2O, 3.85; K_2O, 4.67; P_2O_3, 0.22; H_2O, 0.22; total 101.20.

c. Rapakivi porphyry (type A)*

* The author found biotite granite at a quarry of Pei-ho-pu on the west slope of Nan-shan. However, due to the lack of microscopic data, the author refers to ISHIBASHI's reports for a description of the igneous rocks.

* A description of Type B of rapakivi porphyry is omitted in this paper. Type B refers to a rock containing rapakivi feldspars of a schlieren form. This type is usually found in dikes separate from the stock, but on rare occasions it occurs even in the stock.

In chemical composition, the rapakivi porphyry (type A) is similar to the rapakivi rock reported from Viborg by HACKMAN (1905). However, the rapakivi feldspars contained therein are rather small and have a thick tabular form, differing from the ovoid form of the North Europe specimen. Under the microscope, the orthoclase that previously crystallized out seems to have been gradually replaced by oligoclase as a mantle. The texture of the rock is sempatic porphyritic, and the groundmass contains myrmekite. The oligoclase mantle of megascopic phenocrysts of rapakivi feldspars shows a zonal structure with An_{40} in the core and An_{21} around the edge. Microscopic phenocrysts are plagioclase (An_{40} in the core, An_{21} around the edge), biotite, quartz and green hornblende. The chemical composition(%) is as follows:

SiO_2, 66.36; TiO_2, 0.94; Al_2O_3, 14.91; Fe_2O_3, 1.48; FeO, 2.64; MgO, 1.96; CaO, 3.40; Na_2O, 4.01; K_2O, 4.40; P_2O_5, 0.58; H_2O, 0.20; total 100.88.

d. Dike rocks

They are divided into five groups. Only the rock species will be given.

i. Pegmatite (tourmaline pegmatite)
ii. Aplites (quartz monzonitic, adamelitic, potash alaskitic, salite monzonosyenitic, augite syenitic, etc.)
iii. Rapakivi porphyry (Type B)
iv. Porphyry and quartz-bearing porphyrite
v. Porphyrites

C. Contact-metamorphosed rocks

There are two kinds of contact-metamorphosed rocks; one consists of hornfelses which were formed under thermal metamorphism without the introduction of any external material, and the other of skarns which are the product of replacement by various components supplied from magma to the thermally metamorphosed rocks.

a. Hornfels

Thermal metamorphism of dolomite gave rise to the formation of hornfels of various kinds according to the composition of the original rock. Contact minerals formed in the thermal metamorphism are tremolite, forsterite, diopside, etc. Of the ten standard minerals proposed by BOWEN* as products of thermal metamorphism, higher temperature types, such as periclase and wollastonite, are absent. From the composition and structure, the hornfels can be classified into the following five types:[2)]

(i) Massive calc-hornfels

The principal constituents of massive calc-hornfels are calcite and dolomite, with subordinate forsterite, phlogopite, diopside, titanite, apatite and iron ore. Part of the calcite was newly produced by dedolomitization.[2)]

* BOWEN, N. L. (1940): Progressive metamorphism of siliceous limestone and dolomite; *Jour. Geol.*

(ii) Banded calc-hornfels

Has a banded structure, with bands several millimeters to several centimeters wide, consisting of biotite, forsterite-calcite and dolomite-calcite-diopside. When affected by mineralizing solutions, these bands would change into leuchtenbergite band, humite and magnetite-sulphide bands.

(iii) Andalusite-cordierite hornfels*

Found in the hanging wall at the 118.8 m level in the northern corner of the Nan-shan pit. It is an grey-white compact rock with rose-colored spots. The main constituents are quartz, phlogopite, andalusite, cordierite and feldspar, with tourmaline, zircon and sillimanite as accessory minerals.

(iv) Diopside-anorthite hornfels

At the above 118.8 m level, this hornfels occurs in contact with porphyritic quartz monzonite, and forms the footwall of the andalusite-cordierite hornfels. This is a greenish-gray compact rock. Anorthite ($An_{85\sim90}$), one of the major constituents, is densely commingled with diopside. Subordinate constituents are hastingsite, garnet, epidote, zoistie and calcite.

(v) Hornblende-biotite-quartz hornfels

This hornfels is exposed in a cliff northwest of Nan-shan. Quartz, feldspar and biotite are the major constituents. Subordinate minerals are hornblende, apatite and sericite. Sometimes hornblende is found in a Garbenschiefer form.

b. Skarns

Thermally metamorphosed rocks are partially replaced by skarn minerals along the zone of contact with granodiorite.[2)] There are the following kinds of skarn:

(i) Tremolite skarn. Found in the north shaft and certain other places. Small amounts of diopside and calcite accompany tremolite.

(ii) Actinolite skarn. Occurs as small lenses in the phlogoite-diopside skarn of the new adit of Nan-shan.

(iii) Diopside skarn. Widely exposed in the north shaft. Beside diopside, it contains small amounts of actionolite, calcite and quartz, occasionally accompanied by aggregates of small crystals of allanite.*

(iv) Phlogopite-diopside skarn. Found at Nan-kou and in the new adit of Nan-shan. It consists of green phlogopite and cream-yellow diopside.

(v) Garnet-diopside skarn. Found in the Nan-shan pit and the new Nan-shan adit.

(vi) Garnet-hornblende skarn. Found in the new Nan-shan adit. It is accom-

* Discovered by Ishibashi. According to him, the optical properties of the andalusite are as follows: Index of refraction $\alpha=1.629$, $\beta=1.635$, $\gamma=1.640$, $(-)2V=84°$; pleochroism X=light brownish-red, Y=Z=colorless, absorption X>Y=Z.

* Optical properties of allanite, according to Ishibashi, are as follows: $(-)$ $2V=70°$, $CZ=47°$, pleochroism X=greenish-brown, Y=brown, Z=reddish-brown. Matsuda selected some allanite crystals and had them analyzed by Den-ichi Naito; this revealed that the allanite contained 44.2% Ce_2O_3.

panied by green hornblende, and occasionally contains small lumps of hastingsite and epidote.

(vii) Scapolite-fels.* This is a loose, greenish-gray rock occurring in the hanging wall of the andalusite-cordierite hornfels mentioned previously. It contains small amounts of apatite and titanite.

(viii) Ludwigite-fels.[3] The ludwigite-fels, when weathered, looks like a limonite gossan. It was once mined as an iron ore for a blast furnace at Nan-shan. When fresh, the rock contains stringers of chondrodite, clinohumite and szaibelyite, in addition to a small amount of magnetite. It was found only in the new adit and the open pit of Nan-shan and the Seaside pit. MATSUDA picked up ludwigite crystals under a binocular magnifier and had them analyzed by D. NAITO; the result was as follows (%): SiO_2, 1.62; Al_2O_3, 2.36; Fe_2O_3, 32.02; FeO, 13.22; MnO, 0.11; MgO, 31.55; CaO, 0.31; B_2O_3, 15.52. Black acicular crystals showed a strong magnetism.

4. Ore Deposits

The ore deposits are typical contact deposits. The dolomite, after being thermally metamorphosed by intrusion of the granodiorite, was replaced by skarn zones along the intrusive contact zone, resulting in the formation of ore deposits. It is probable that the mineralization continued throughout, that is, starting with the pegmatite intrusion the country rocks underwent pneumatolysis, replacement by skarn zones, carbonatization and chloritization, succeeded by the precipitation of metallic sulphides in a hydrothermal solution. However, such continual processes of mineralization are not found in individual deposits. This may be attributable to the scope of magmatic differentiation. For the formations of ore deposits, the most important factor is the relation between mineralization and geologic structure, especially the fissure system in which ore minerals would be deposited. It is regretted that any conclusive comments cannot be given here, due to the lack of exploration data. The author believes that in an early stage of mineralization, boron and part of the iron were introduced by the action of pneumatolysis, but the absence of other pneumatolytic minerals (such haloids as fluorite) suggests that the pneumatolysis was of a small scale. Skarnization is represented by diopside, in association with allanite, scheelite, bismuthic minerals, molybdenite, etc. The sulphides in the high-grade copper ore replacing skarn minerals in irregular form are thought to have been produced in the hydrothermal stage.

A. Distribution of ore deposits

Ore deposits are found in the dolomite, within a 500 m wide area, along the zone of contact with granodiorite. Ores are scattered in the skarn zones. The maximum length of ore bodies is several tens of meters. Major ore bodies are those

* According to ISHIBASHI, the optical properties of the scapolite are $(-)\omega=1.554$ and $\varepsilon=1.542$, which suggest that the mineral is connected with dipyrie.

of Nan-kou, Nan-shan open pit, Nan-shan new adit, north shaft and Seaside pit, from north to south, with a total extension of 2 km. Borate minerals are found in the Nan-shan open pit and new adit and in the Seaside pit. Exploration for copper ore was carried out in the north shaft.

B. Ore deposits of the north shaft

Deposits consist chiefly of diopside skarn impregnated with metallic minerals. The skarn was also affected by hydrothermal alteration, resulting in the formation of vein-like bodies of sulphide ore containing more than 3% Cu. The metallic minerals in the impregnated portion are mostly magnetite, accompanied by subordinate amounts of gold, bismuth, bismuthinite, tetradymite,[2)] molybdenite, scheelite* and chalcopyrite; those in the vein-like bodies are chalcopyrite, pyrrhotite and pyrite.

C. Mode of occurrence of some metallic minerals

The mode of occurrence of some of the metallic minerals is excerpted here from Ishibashi's report.

a. Bismuthic minerals

Native bismuth always occurs in association with bismuthinite, showing an eutectic relation. Chalcopyrite and pyrrhotite are found as inclusions in the native bismuth. Tetradymite occurs as inclusions in the bismuthinite. Native gold, that can be obtained by panning, is thought to have a close relationship to the bismuthic minerals.

b. Chalcopyrite

Almost always accompanied by pyrrhotite, and contains some zincblende stars, cubanite and valleriite.

c. Pyrrhotite

Occasionally occurs as small irregular particles included in zincblende. In the oxidized zone it changes into marcasite and pyrite, presenting a bird's eye structure.

5. Some Genetical Considerations

The ore deposits at Hua-tung-kou are typical contact deposits which occur along the zone of contact between the Precambrian dolomite and granodiorite. The dolomite was thermally metamorphosed by intrusion of the granodiorite and altered to hornfels of various kinds. These hornfels have undergone a series of mineralizing actions, starting with pegmatite intrusion, going through formation of skarns in association with pneumatolysis and ending with the deposition of sulphide ores by a hydrothermal process.* Worth special mention is the impregna-

* Hand-picked concentrate showed 0.93% WO_3.

* Minerals newly formed from the time of granodiorite intrusion to the end of mineralization amount to about 50 species.

tion of borates, allanite, scheelite, molybdenite and bismuthic minerals, in association with the formation of skarns. It is an important fact that molybdenite is a common mineral in the contact deposits in South Manchuria, as exemplified by the Hua-tung-kou mine. It gives a clue to the study of the metallogenetic epoch and petrographic provinces of Manchuria, as well as for the future prospecting of ore deposits.

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