METALLOGENETIC PROVINCES OF NORTHEASTERN HOKKAIDO, JAPAN

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Introduction

The mine field in northeastern Hokkaido has been developed since about 1850. At present, there are many productive mines; some examples are the Konomai (gold, silver, selenium), Itomuka (mercury), the Shimokawa (copper, iron sulphide, gold), the Akan-Io (sulphur), and the Kokuriki (iron) mines. The production of mercury in this district was about 160 tons in 1958, while that of all Japan was about 200 tons. The production of gold in this district was about 3.5 tons in 1958 which accounts for about 40 percent of that of all Japan. And so this district is one of the valuable mining districts in Japan.

It is well known that the Japanese Islands belong geologically in the circum-Pacific zone. Northeastern Hokkaido in the northern end of Japan is situated in the intersection of the Honshu (the Main Island) arc and the Kurile Islands arc. The geology and the ore deposits in this district have the characters of those in both arcs.

Support for an established theory is not always afforded from some considerations on the metallogenetic provinces in the district since WATANABE'S (1923) statement on the geological distribution of the important ore deposits of Japan. For example, the northeastern Hokkaido region is divided into the Itomuka-type mercury metallogenetic province and the Konomai-type gold metallogenetic province by TSUBOYA (1950) ; he and others (1956) established the Nemuro-Shiretoko metallogenetic province and Kitami metallogenetic province.

TURNEAURE (1955) states that the limits of the individual provinces usually are difficult to places. The writer (1957) has proposed the term "geological unit" agreeing with the subdivisions of the Kitami metallogenetic province: for example, central Kitami. It should be emphasized that most of the igneous activities are connected with ore deposits in this district (URASIMA: 1958). It is considered that the formations of both syngenetic deposits and epigenetic deposits are closely connected with sedimentation, igneous activities and tectonic movements.

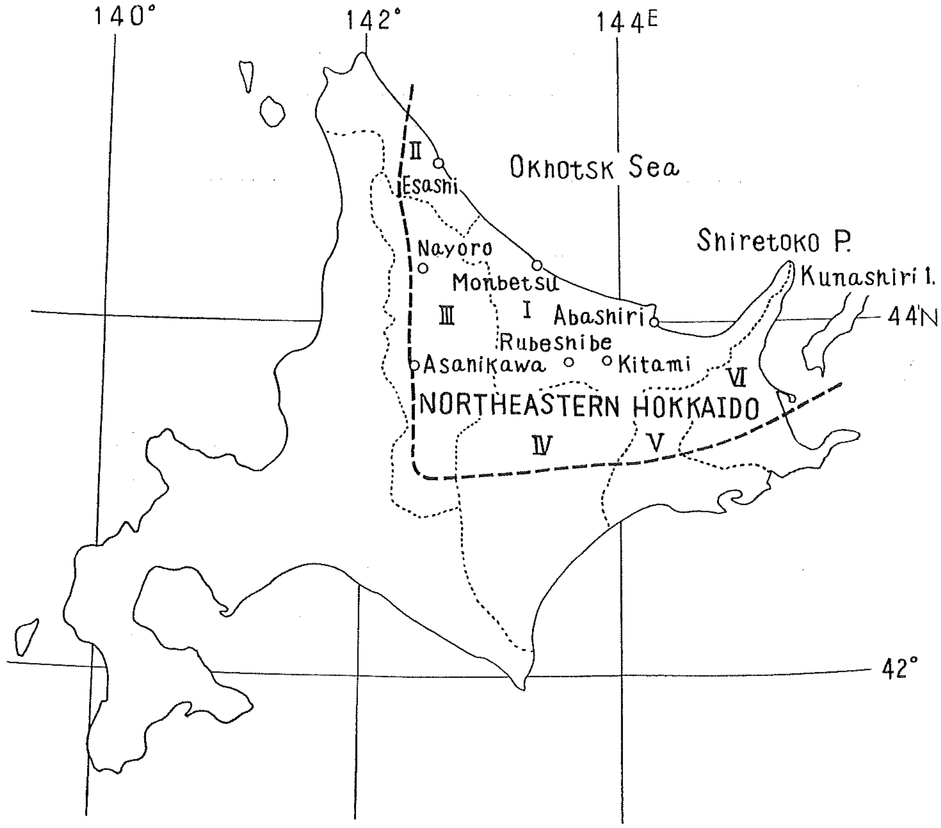

Fig. 1. Index map showing location of northeastern Hokkaido.
I, Abashiri (Kitami); II, Soya; III, Kamikawa; IV, Tokachi; V, Kushiro; VI, Nemuro.

BATEMAN (1950) states that metallogenetic provinces may contain mineralization of more than one epoch, each superimposed upon the other, but essentially of the same type. In northeastern Hokkaido, however, mineralization in one epoch was different from that in another with a few exceptions. Accordingly, the metallogenetic provinces must be divided according to each metallogenetic epoch as proposed by MURAKOSHI and HASHIMOTO (1956) or by WATANABE and IWAO (1959).

ISIBASI (1958) emphasizes the constituents of ore deposits, ore textures and ore paragenesis as defining communities among ore deposits in the base metal provinces of Hokkaido. A division of the metallogenetic provinces of Japan mainly based on the sorts of the ore was established by SEKINE (1956), for example. It is an important character of a metallogenetic province that ore deposits distributed within a certain area have some common features upon which basis types of ore deposits may be subdivided. One metallogenetic province in northeastern Hokkaido usually contains ore deposits of more than one type, because of the complexities of geologic structure and the complicated distributions of the ore deposits.

Geological setting of northeastern Hokkaido

Structures.—Geologically speaking, Hokkaido is divided into southwestern Hokkaido and eastern Hokkaido by a boundary with N-S direction. The former is the north extremity of the inner zone of the Honshu arc, and the latter is the main part of Hokkaido. The geological subdivisions of the main part of Hokkaido are as follows: the Kamuikotan zone, the Hidaka zone and the Tokoro zone with N-S direction; the inner Kurile zone and the outer Kurile zone extending in E-W direction. Similar zoning is also shown by the distributions of the BOUGER's anomaly (TSUBOI: 1954) and geomagnetic anomally (SEINO: 1958).

N-S direction, that is the direction of the Hidaka orogenic zone (HUNAHASHI: 1957), is clearly recognized in the western part of northeastern Hokkaido, while the structures with E-W direction, i.e., the direction or the Kurile volcanic zone develop towards the eastern area. Distribution and strikes of ore deposits are mostly controlled by complicated assemblages of structural features with the Hidaka and the Kurile directions.

"Northeastern Hokkaido" in this paper is not taken to include the Kamuikotan zone, the south half of the Hidaka zone nor the outer Kurile zone, because these zones do not generally contain examples of post-Mesozoic mineralization .

Pre-Tertiary system.—The existence of a Palaeozoic system in northeastern Hokkaido is yet unconfirmed. It is considered that the pre-Tertiary system in this district consists of the Mesozoic system: mostly Jurassic (HASHIMOTO: 1952), partly Cretaceous (G. S. Hokkaido: 1958).

The basement of the Tokoro zone mainly consists of diabase containing pillow lava and schalstein formations with sandstone, shale, chert and limestone; they may be Jurassic geosynclinal formations (SUZUKI: 1958). Lower Cretaceous formations consisting mostly of shale and sandstone are distributed along the northwestern and southern borders of this zone; igneous materials and ores are poor in these formations.

Slate, shale, sandstone, schalstein and diabase with accompanying chert, limestone and conglomerate constitute most of the basement of the northern Hidaka zone; the formations are called "Hidaka series", their geological epoch is probably pre-Cretaceous. Cretaceous sediments are found along the western border of this zone. The Hidaka series are generally intruded by basic rocks—diabase and gabbro, rarely serpentine—in the west side of the zone and by intermediate or acidic rocks—diorite, granite and porphyry—in the east side of the zone; sometimes hornfels, amphibolite or mignatite are found in the zone. Most of these igneous and metamorphic rocks seem to have been formed in the late Cretaceous epoch though not simultaneously (HUNAHASHI: 1957). Some of the intrusives in the east side may have formed during the Tertiary epoch. Basic igneous rocks and pyroclastic materials are found symmetrically in abundance in the eastern and western marginal zones of the distribution area of the pre-Tertiary system.

These tectonic zones are rich in iron, manganese and cupriferous iron sulphides ore deposits accompanied by basic igneous activities.

Tertiary system.—Palaeogene sediments are not developed in the northeastern Hokkaido with the exception of the southern part of the Tokoro zone, where no ore deposits are found. Palaeogene intrusives have not been reported as evident in this district, but the latest effect of the Hidaka orogenic movements which seem to have acted until in the Tertiary may have brought som igneous activity and mineralization. Some of the Intermediate and acidic intrusives on the east side of the Hidaka zone probably belong to the Tertiary igneous rocks in the latest stage of the movements though definite evidence is almost unobtainable in the occurrences.

In this district, pyroclastics and volcanics are very abundant in the Neogene Tertiary system, of which the distribution area is not exactly continuous. The relationship with the basements, orders of formations, more or less of green tuff and sorts of igneous rocks are dissimilar according to places.

So, it is considered that the Tertiary geologic province of the northeastern Hokkaido is subdivided into the following "geologic units" (URASIMA: 1957) : the western Kitami and the Daisetsu basement on the west side of the northern Hidaka zone, the spinal Kitami, the Kitami-Tokachi, and the central Kitami on the east side of the northern Hidaka zone, the Abashiri in the Tokoro zone and the Shiretoko in the inner Kurile zone.

These units are important criteria for the establishment of subdivision of the Tertiary metallogenetic province in northeastern Hokkaido. Miocene formations usually cover the pre-Cretaceous, sometimes the Cretaceous or the Palaeogene series. The latter are found along the southern marginal zone. There are Tertiary ore deposits in the above complicates, especially Neogene Tertiary and pre-Cretaceous rocks.

Sediments from Miocene to Pliocene are distributed in all the above mentioned geologic units, but in respect to their stratigraphic orders and the properties of their constituents they are not similar to one another. It is geologically recognized that the marginal zone of this province is in striking contrast to the inner zone (URASIMA and OKADA: 1956).

Green pyroclastic sediments in Miocene are more abundant in the marginal zone, for example, in the Shiretoko "unit province", than in the inner zone. In the marginal zone, it is often difficult to distinguish between green tuff and propylite. Holocrystalline intrusives are sometimes found there. The Shiretoko unit has an anticlinal axis with the Kurile direction (YAMAGUCHI et al.: 1953). Quaternary volcanoes are distributed within the zone. Such a zone seems to be a tectonic one which was changing from a grabenlike basin to an anticlinal area in the Miocene. There are more base metal ore deposits than gold-silver ones in the Shiretoko zone.

Rhyolite and its pyroclastics containing welded tuff develop widely over lower normal sediments of the Miocene in the inner zone, specially in the central Kitami "unit province" (URASIMA et al.: 1953). Many gold-silver ore deposits are scattered about in such areas, but according to recent studies rhyolite is regarded to occur in bodies smaller than those shown in preceding maps. Miocene andesite in the area exhibits mostly dyke-form; it is weakly and heterogeneously propylitized.

Basalt in the Shiretoko unit has sometimes been altered by a hydrothermal solution which seems to have acted in upper Miocene; while basalt in the central Kitami unit is usually fresh and seems to have acted in Pliocene in a post-Tertiary mineralization (URASIMA: 1953).

It is yet unconfirmed whether the above-mentioned plutonic or hypabyssal rocks on the side of the Hidaka zone appeared in the Mesozoic or in the Tertiary; but some bodies seem to intrude in the Tertiary, because evidence is reported that one body is formd throughout the Tertiary sandstone beds (G. S. Hokkaido: 1958). Intermediate or acidic intrusive rocks which penetrate Miocene formations are found in some places, and most of them occur in the units belonging to the marginal zone (URASIMA and OKADA: 1956).

Although ore deposits are usually not recognized in the Miocene intrusives except gold-silver of the Harutomi mine, it is considered that mineralization in the Neogene Tertiary has some relation with such rocks because of the intimate association of the ore depostis and the rocks. In addition, some sorts of andesite, mostly in the marginal zone, and rhyolite, mostly in the central zone, are known as volcanic rocks of after-main-Tertiary-mineralization (URASIMA: 1958)—perhaps in Pliocene. Most of the Pliocene sediments, the Shanafuchi group and its contemporaries, are also tuffaceous, and their distribution areas tend to occur along the side of Miocene areas.

Quaternary system.—Welded tuff (SUZUKI: 1957) and its contemporaneous ash formations in the Diluvian epoch develop mostly in the marginal zones of Tertiary distribution areas. Recent volcanic groups, which include the Kurile (Shiretoko-Akan), the Tokachi and the Daisetsu volcanic groups or zones are within a more restricted zone. Few mineralizations have recently become known which accompanied Diluvian volcanism, while recent volcanism that is represented by variable andesite belonging mostly to a hypersthen rock series and partly to a pigeonite rock series (ISHIKAWA: 1958) produces sulphur, iron and manganese ore deposits. Placer ore deposits along the coast and rivers of the Okhotsk Sea are mostly derived from the products of above mentioned igneous activities from Mesozoic to recent.

Subdivision of the metallogenetic province northeastern Hokkaido

It is desirable that any grouping of ore deposits is in harmony with subdivision of a metallogenetic province based upon the geologic unit in this district. There remain unsolved problems in some systematic or genetic classifications of ore deposits in northeastern Hokkaido, for example, depth and temperature classification (LINDGREN: 1933), minero-chemical classification (NIGGLI: 1929), ore association classification (SCHNEIDERHÖHNS 1941), because of "the infinite number of natural phenomena" (NOBLE: 1955) in ore deposits. In this paper, there are introduced for convenience some types of ore deposits to show their characters in respect to ore association and other elements.

The mineralization epochs of some ore deposits are yet unconfirmed. It is, however, reasonable that the metallogenetic provinces in northeastern Hokkaido should be considered to belong to each metallogenetic epoch.

The metallogenetic provinces, "unit provinces", kinds or types of ore deposits in each province and some examples of them are:

1. Eastern Hokkaido metallogenetic province (Mesozoic mineralization).
   a. Tokoro unit province.
      Copper, iron sulphide (pyrite-chalcopyrite type)—Bushi.
      Manganese (braunite type)—Kitami-Mangan, Wakasa, Kunneppu.
      Iron, Manganese (manganiferous hematite type)—Kokuriki, Nikura.
   b. Northern Hidaka unit province.
      Copper, iron sulphide (pyrite-chalcopyrite type)—Shimokawa, (magnetite-pyrrhotie type)—Shikaribetsu; (pyrrhotite-chalcopyrite type)—Kamie.
      Manganese (rhodochrosite-rhodonite type)—Sangoi, Taiyo, Shibetsu.
2. Kitami metallogenetic province (Tertiary mineralization).
   a. Spinal Kitami unit province.
      Mercury—Uttsu.
      Copper (vein type)—Nakakoshi.
      Gold (quartz type)—Takinoue.
   b. Western Kitami unit province.
      Copper, lead, zinc, iron sulphide (vein type)—Imai-Motokura, Jotoku.
      Gold, silver (quartz-adularia type)—Hokuryu, Sanru.
   c. Daisetsu basement unit province.
      Mercury—Aizankei, Yunosawa.
      Gold, silver (quartz-adularia type)—Tokusei.
      Copper, lead, zinc, iron sulphide (vein type)—Kunimitsu, Otonosawa.
   d. Kitami-Tokachi unit province.
      Mercury—Itomuka, Oketo.
      Kaolin—Seta.
      Gold, silver (quartz-adularia type)—Harutomi.
   e. Central Kitami unit province.
      Mercury—Ryushoden, Yasoshi.

Gold, silver, selenium (quartz-adularia type)—Konomai, Numanoue, Kitanoo, Yahagi.
Copper, lead, zinc, iron sulphide (vein type)—Kitami, Setose; (kuoroko type)—Fumi.

f. Abashiri unit province.
Mercury—Ubara.

g. Shiretoko unit province.
Copper, zinc, lead, iron sulphide (vein type)—Toa; (kuroko type)—Nemuro.

3. Okhotsk metallogenetic province (Quaternary mineralization).

a. Daisetsu unit province.
Sulphur (molten sulphur type)—Tokachi; (sablimated and disseminated sulphur type)—Asahidake, Tokachi, Hishinaka-Tokachi.
Iron (limonite-jarosite type)—Nittetsu-Tokachi.
Manganese (wad type)—Tokachi-Mangan.

b. Akan unit province.
Sulphur (molten sulphur type)—Shiretoko-Iozan; (sublimated and disseminated sulphur type)—Akan-Io, Atosanupuri.
Iron (limonite-jarosite type)—Utoro, Horodomari, Nippo.

c. Bihoro unit province.
Iron (limonite type)—Bihoro.

d. Horonai unit province.
Iron (limonite type)—Horonaihokuyu.

e. Tonbetsu unit province.
Gold (native gold sand type)—Tonbetsu.
Chrome and platinum (chromite and iridosmine sand type)—Tonbetsu.

f. Northern Okhotsk unit province.
Titanium (ilmenite sand type)—Sakaeoka, Saruru, Monbetsu.
Gold (native gold sand type)—Esashi, Yasoshi.

g. Southern Okhotsk unit province.
Iron (magnetite sand type)—Saroma, Misaki, Shimatokari, Chashikotsu.

Mesozoic metallogenetic province of northeastern Hokkaido (Eastern Hokkaido metallogenetic province)

The main ore deposits formed in the Mesozoic Era are those of manganese, iron, and cupriferous iron sulphides all of which may be closely related with basic igneous activities. Some of the base metal or gold veins have been considered to accompany Mesozoic granitic rocks, but the evidences are deemed inconclusive (Fig. 2).

As the pre-Tertiary system is widely covered by the Cenozoic system, the distribution area of above-mentioned ore deposits that can now be recognized is not equivalent to the Mesozoic metallogenetic province. It is considered that all the Tokoro and northern Hidaka geologic units belong in this province, which are, in wide sense, named the eastern Hokkaido metallogenetic province including moreover the Kamuikotan, the southern Hidaka and the outer Kurile units.

Tokoro "unit province."—The main consistuents of the Tokoro zone are Jurassic and Cretaceous systems; ore deposits are known from the Jurassic system to be distributed in its eastern half. There are manganiferous iron ore deposits (SUZUKI and OHMACHI: 1956) and manganese ore deposits (URASIMA: 1957) in the complicates which consist of diabase, schalstein, chert and limestone. The diabase is rich in pillow lavas (SUZUKI: 1954) showing effusive facies with glassy and intersertal textures; examples are found in the neighborhood of the Kokuriki mine. There are tabular or lenticular ore bodies in or along red chert. In such an arrangement two sorts of ore deposits have similar geological milieu. However, both are distributed in the separate areas.

The manganiferous deposits crowd within the northeastern part of the mineralized area,—"the Tokoro-type group," while the manganese ore deposits are arranged from its west side to the southern zone—"the Kitami-type group". The former ore bodies are folded more remarkably than the latter. Wall-rock alteration is usually not obvious. Red radiolarian cherty zones along the ore bodies do not form a silicified zone, but it seems reasonable to regard the material as a kind of gangue quartz. Ores of the Tokoro-type group consist mostly of manganiferous hematite, (TAKABATAKE: 1958) while the main ore mineral from the Kitami-type group is braunite (URASIMA: 1958). Accordingly, the proportional relations among Fe, Mn and SiO which are the main chemical compositions in ores can clearly be distinguished between the former and the latter, with no middle class known. Although there remain some opinions that the above mentioned ore deposits were formed by replacement (YOSHIMURA: 1952a, b), they are usually classified in a sort of exhalation deposits (SCHNEIDERHÖRN: 1941) accompanied by evidences of basic igneous activities in a geosynclinal zone (SUZUKI: 1958, SUZUKI and OHMACHI: 1956, TAKABATAKE: 1956, WATANABE: 1957). There are, furthermore, small cupriferous iron sulphide ore deposits of which the main constituents are pyrite and chalcopyrite in schalstein, occurring separately from manganese and iron ore deposits.

Northern Hidaka "unit province."—The basements of northern Hidaka unit are to be found in the neighborhoods of Esashi, Otoshibe, Okushibetsu and northern Tokachi; they consist of the Hidaka series and igneous rocks. This unit is a continuance of the southern part of the Hidaka

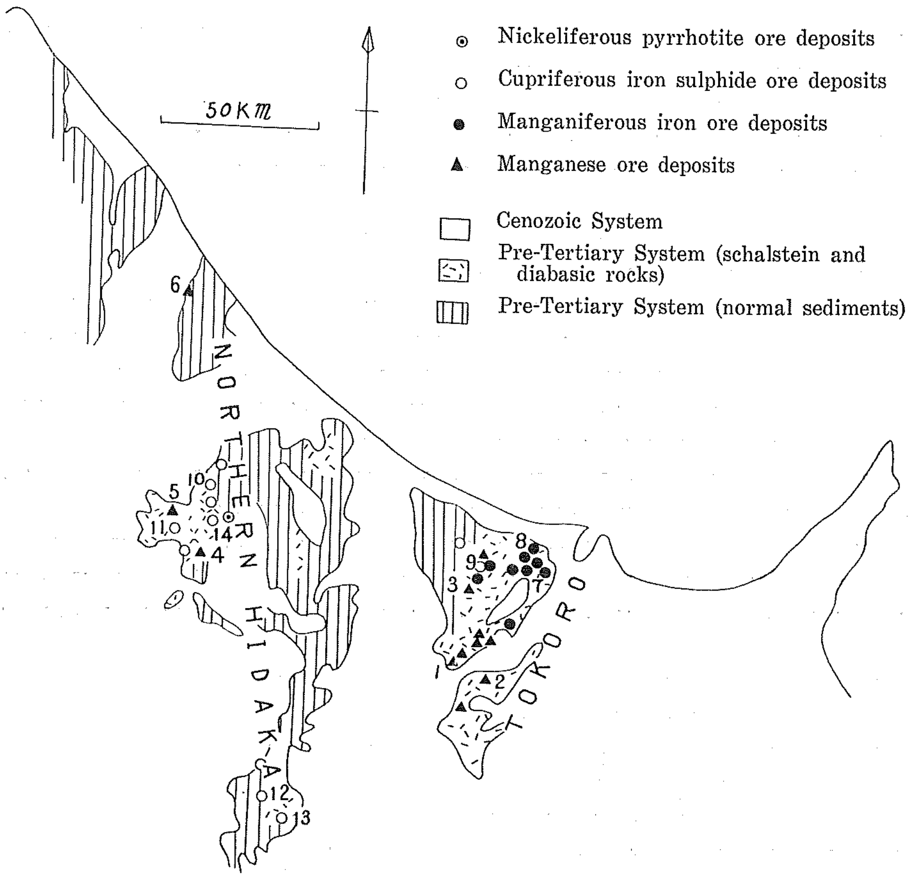

Fig. 2. Sketch map showing "Eastern Hokkaido metallogenetic province."

Manganese ore deposits: 1, Kitami-Mangan; 2, Hinode-Mangan; 3, Wakasa, 4, Sangoi; 5, Shibetsu, 6, Kamitokushibetsu.

Manganiferous iron ore deposits: 7, Kokuriki; 8, Nikura.

Cupriferous iron sulphide ore deposits: 9, Bushi; 10, Shimokawa; 11, Kamie; 12, Shintoku; 13, Shikaribetsu.

Nickeliferous pyrrhotite ore depoits: 14, Okushibetsu.

orogenic zone. Both portions are sometimes called the Hidaka metallogenetic province; they are characterized by cupriferous iron sulphide, manganese and nickel-bearing iron sulphide ore deposits.

It is considered that cupriferous iron sulphide ore deposits are imbedded within the shear zones in or near diabasic rocks in non-metamorphic areas (HUNAHASHI: 1957) and that the mineral assemblages are diversified according to the varieties of the geological environment of the deposits (SAWA: 1958). Deposits worked by the Shimokawa mine mostly produce pyrite-chalcopyrite-type ore; magnetite or pyrrhotite abound in the ores of the Shikaribetsu mine and the Kamie mine, which are situated in a thermal metamorphosed area. It has been considered that such deposits were formed by hydrothermal replacement in the shear zone; an example is found between slate and diabase dykes at the Shimokawa mine. But there occur some problems concerning the genesis of such deposits, as most of the diabases are now recognized as pillow lava conformable to the slate there. The occurrence of manganese ore deposits is similar to that of the cupriferous iron sulphide ore deposits; there are produced supergene manganese oxides (HARADA: 1949), and hypogene manganese minerals such as rhodochrosite and rhodonite (SAKO: 1957). The latters are found in small amounts in manganese ore deposits of the Tokoro unit. The Tokushibetsu deposits consists of manganese and iron sulphide parts, but it is doubtful whether both would have been caused by the same mineralization.

Nickeliferous pyrrhotite ore deposits are known at the Okushibetsu mine; they seem to be late magmatic ore deposits in gabbro after diabase near cupriferous iron sulphide ore deposits (HUNAHASHI: 1957). It is, thus, of interest that the Tokoro and northern Hidaka "unit provinces" have symmetrical features not only in respect to geology but also in respect to ore deposits.

Tertiary metallogenetic province of northeastern Hokkaido (Kitami metallogenetic province)

It is considered that base metal (copper-lead-zinc-iron sulphides), gold-silver and mercury ore deposits in northeastern Hokkaido were formed by mineralization related with intrusive and effusive igneous activities in Tertiary, though the evidences are slender as regards some gold-quartz veins and mercury deposits at the northwestern part of the province. The area of the distribution of such deposits is named the Kitami metallogenetic province. It includes the greater part of the eastern Hokkaido metallogenetic province except for the Kamuikotan and southern

Hidaka units (Fig. 3).

According to the above-noted geologic units and feature of the distribution of the ore deposits, this province is subdivided into the following seven metallogenetic units: spinal Kitami, western Kitami, Daisetsu basements, Kitami-Tokachi, central Kitami, Abashiri and Shiretoko.

Spinal Kitami "unit province."—Intermediate or acidic intrusives penetrating the Hidaka series are arranged in this unit with a general trend from north to south. As Tertiary sediments are almost absent, there is no corroboration of those intrusives and connected ore deposits to any definite geological epoch. It is considered that the mineralization may at the least be later than that of the Hidaka and Tokoro units according to the geologic structures.

It is recently found that the ore deposits in this unit usually contain interesting mineral assemblages such as the following: gold-tourmaline-quartz veins of the Chuko mine, gold-pyrrhotite-arsenopyrite-quartz veins of the Takinoue mine (FUKUTOMI: 1949) and pyrrhotite-arsenopyrite-bismuthinite-chalcopyrite-quartz veins of the Nakakoshi mine. These assemblages seem to exhibit evidence of formation under a condition of somewhat high temperature (INGERSON: 1955) and it is induced that the mineralization was related with the intrusive rocks.

Western Kitami "unit province."—Neogene Tertiary sediments in this province contain green tuff. It is regarded that those sediments develop separately in two or three basins. The main deposits are copper-lead-zinc-iron sulphide, gold-silver and mercury. Copper-lead-zinc-iron sulphide ore deposits appear as veins in green tuff and propylite such as those of the Imai-Motokura and Jotoku mines (BAMBA et al: 1958). Surrounding them ,there are adularia-quartz-type gold-silver veins in Miocene rocks in such mines as the Utanobori, Hokuryu, Sanru and others. Their wall-rock alteration which "is commonly pervasive in the vicinity of hydrothermal ore deposits" (SCHWARTZ: 1955) is usually stronger than that of veins in the Hidaka series of the spinal "unit province."

Daisetsu basement "unit province."—The Neogene Tertiary system which forms the basement of the Daisetsu and the Tokachi volcanic groups is rich in green tuff and propylite. Though is an obvious tendency of distribution of ore deposits because of the development of younger lavas and pyroclastics, there is evidence enough to justify the establishment of a metallogenetic unit consisting of the base metal and mercury ore deposits.

Molybdenite and hübnerite are recognized from some base metal ore deposits; such facts are considered as evidence of a sort of telescoping phenomena in the hydrothermal ore deposits (OHMACHI: 1958) and a deposition within tectionic zone (*I*SHIBASI: 1958). It is quite within the bounds of possibility that there is some genetic relation between the Tertiary deposition of hübnerite and rhodochrosite and the existence of rhodochrosite-rhodonite-typed manganese deposits in the Mesozoic system. There are mercury ore deposits in propylite of the Aizankei and other mines near the base metal ore deposits, but no overlapping mineralization of two types of deposits is recognized.

Kitami-Tokachi "unit province."—The Miocene series which extends from southwestern Kitami to northern Tokachi abound in green tuff and propylite as is also the case in the Daisetsu basement and in the Shiretoko unit provinces, but the series has also some characters of Miocene series in central Kitami (URASIMA and OKADA: 1956).

Main ore types in this unit are mercury-kaolin and gold-silver. Ore deposits of the Harutomi mine located in the central part of this unit consists of many gold-silver-adularia-quartz veins in or near holocrystalline intermediate and acidic intrusive rocks. There are also a few interesting occurrences of tourmaline, garnet and biotite contained in the altered wall-rocks. Mercury ore deposits are distributed not only in the Kitami side but also in the Tokachi side; they are somewhat out of the mercury zones in the central Kitami unit province and there is no established theory as yet about the distribution of all mercury ore deposits in Hokkaido. Mercury ore deposits of the Itomuka mine, the largest mercury mine in Japan, are mercury-quartz-carbonate veins which sometimes contain abundant iron sulphides or montmorillonite in propylite and tuffaceous rocks. The ratio of native mercuy to cinnabar shows one of the highest values (about 7 : 3) in the world. Kaolin ore bodies formed by hydrothermal alteration are accompanied by mercury ore deposits of the Seta and the Oketo mines (KISHIMOTO and WATANABE: 1956). The coexistence of mercury and gold veins at the Seta mine seems to show a mutual close relationship between the two types.

Central Kitami "unit province."—A zone from the city of Monbetsu to the town of Rubeshibe is one of the Neogene volcanic areas in which there is little green tuff but abundant rhyolitic tuff (URASIA: 1958). As the workable deposits of the Kitami metallogenetic province are distributed mostly in this unit, it is sometimes called the Kitami mining district. Mineralized region in this unit have been comparatively well studed, because there are few post-mineralization rocks. The region is divided into west and east zones: they have about N-S trend which seems to be related with the tectonic zone of the basement and the long axis of Miocene sedimentation (URASIMA: 1957). The extremities of the zones sometimes extend to adjoining units.

Base metal ore deposits within the western zone are mostly copper-lead-zinc-iron sulphide veins in Mesozoic sediments, but it is considered that they were formed in the Tertiary epoch. The parallel veins group of the Kitami mine, one of the largest-scale base metal ore deposits in Hokkaido, which lies contiguous to the south of the Konomai gold-silver mine, is divided into iron sulphide, lead-zinc-iron sulphide, copper-lead-zinc-iron sulphide, copper-iron sulphide and barren quartz zones from north to south. These veins often contain adularia which is one of the main constituents of gold-silver ore deposits in this province. Pyrrhotite, zinc stars in chalcopyrite and chalcopyrite dots or strips in sphalerite are recognized in ores in the central part of the group; these phenomena seem to indicate a high temperature of the ore formation (SUGAKI and YAMAE: 1952) similar to one in the spinal "unit province". Ore deposits of the Fumi mine in the east zone lie in clayey altered tuff of Miocene; they are perhaps not vein-type but "kuroko"-type.

Many gold-silver ore deposits mostly occur in a double file and form the so-called Kitami gold mining district. These mineralized zones are located near the west and east sides in the area of the Konomai formation and related volcanics; the strike of the veins in above zones usually make a right or oblique angle with the general trend (N-S) of the mineralized (silicified) zone (URASIMA: 1957). The main constituents of the gold-silver ores are everywhere quartz and adularia sometimes accompanied by calcite. High grade ores usually contain so-called "ginguro", i.e. coloform black bands, but the Konomai gold-silver-selenium mine produces in small quantity an ore with green clay mineral bands and a white clayey ore containing montmorillonite and kaolin; "the Showa-Kitanoo type ores" seem to be a sort of clayed residual ore (WATANABE: 1923, BAMBA and SAITO: 1959).

There are mercury ore deposits along the somewhat outer sides of zones; most of them are to be found at the northern and southern parts of the zones. The wall-rocks of the deposits are the Tertiary and its basement rocks the Ryushoden mine produces cinnabar-kaolin ore formed by dissemination against Tertiary sandstone, while ore bodies of the Tokoro mine are vein-shaped in the Hidaka series. Mercury ore deposits in the Kitami metallogenetic province have been grouped into the circum-Daisetsu volcano mercury ore deposits (YAJIMA: 1950) ; they appear to be a distribution along some tectonic zones sorrounding the spinal Kitami unit province. Three sorts of ore deposits in central Kitami are mostly within the same mineralized zones; their overlapping mineralizations are rarely recognized:

for example, the existence of cinnabar in late stages of some gold-silver veins, the coexistence of some gold-silver and iron-sulphide veins.

Abashiri "unit province."—The above mentioned units mostly lie on the Hidaka unit, while the Abashiri unit lies upon the Mesozoic Tokoro unit. The Neogene Tertiary system in this "unit province" is abundant in normal sediments and poor in volcanic products (SASA and INOUE:

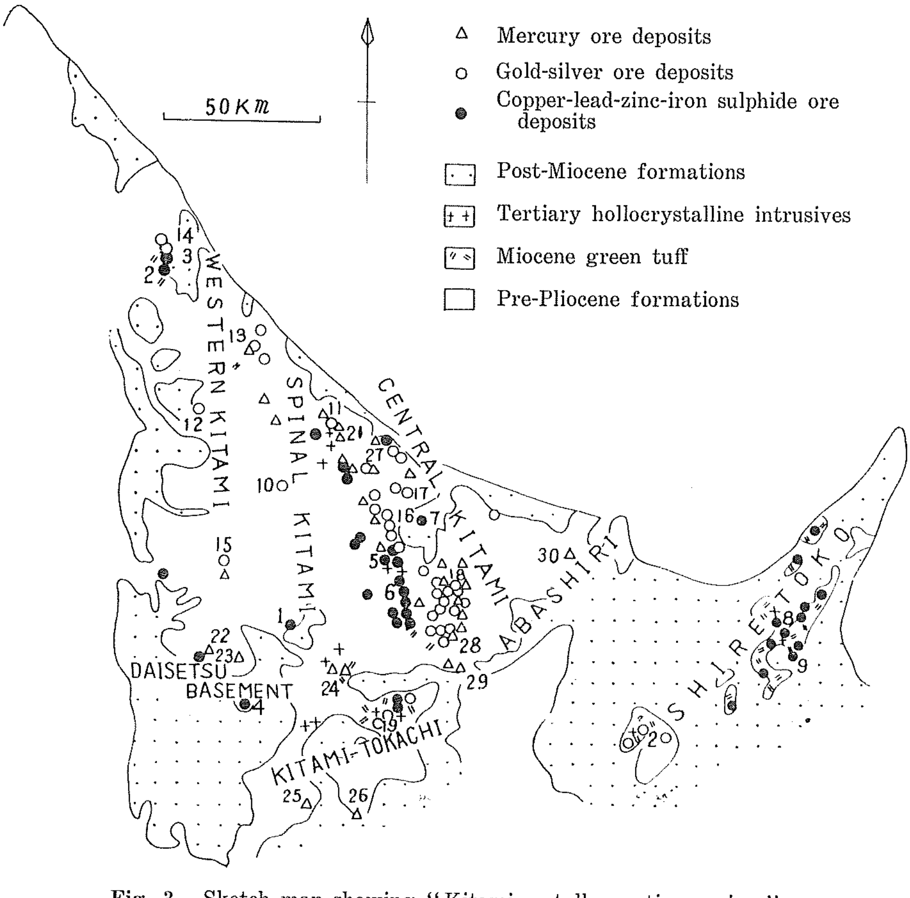

Fig. 3. Sketch map showing "Kitami metallogenetic province".

Copper-lead-zinc-iron sulphide ore deposits:
1, Nakakoshi; 2, Jotoku; 3, Imai-Motokura; 4, Kunimitsu; 5, Kitami (Inaushi); 6, Setose; 7, Fumi; 8, Toa; 9 Nemuro.

Gold-siluer ore deposits; 10, Takinoue; 11, Chuko; 12, Sanru; 13, Hokuryu; 14, Utanobori; 15, Tokusei; 16, Konomai; 17, Numanoue; 18, Kitanoo; 19, Harutomi; 20, Okushunbetsu.

Mercury ore deposits; 21, Uttsu; 22, Aizankei; 23, Yunosawa; 24, Itomuka; 25, Yuyanbetsu; 26, Tokachi; 27, Byushoden; 28, Tokoro; 29, Oketo; 30, Ubara.

1939). Also, ore deposits are not recognized there except for small-scale mercury and iron sulphide ore deposits.

Shiretoko "unit province."—The Neogene Tertiary system in the zone extending from the neighborhood of Lake Akan to the Shiretoko Peninsula is very abundant in effusive and intrusive rocks and green tuff. Related with those igneous products, there are many base metal and some gold-silver ore deposits in the unit, but no mercury ore deposits have yet been found. Though younger volcanics cover some parts of the mineralized area, three zones which contain base metal ore deposits are recognized: northern, central and southern zones with the same direction as the Shiretoko Peninsula (the Kurile direction). It is considered that these zones represent the axis and wings of an anticlinal structure (YAMAGUCHI et al.: 1953). Most of the vein-type ore deposits occur in the central zone, while the "kuroko"-type ones develop in the southern zone. The Nemuro mine has such representative ore deposits consisting of chalcopyrite-galena-sphalerite-gypsum ore.

Gold-silver-adularia-quartz veins are known in the southern basements of the Akan volcanic group (SAITO and WATANABE: 1955) ; they are like the gold-silver veins in the Daisetsu basement unit.

Quaternary metallogenetec province of northeastern Hokkaido (Okhotsk metallogetic province)

Some iron, manganese and sulphur ore deposits accompanied by Quaternary volcanism are distributed in a western extension region of the Kurile volcanic zone along the southern edge of the Okhotsk Sea; also, placer ore deposits of titanium, iron, gold, platinum and chrome develop in the district along the seashore and along the rivers flowing into the Sea. The latter deposits are indirectly related with igneous activities.

The above mentioned deposits lie within a limited zone of the Kitami metallogenetic province and form a quaternary metallogenetic province which is named the "Okhotsk metallogenetic province." It is subdivided into the following: the Daisetsu, Akan, Bihoro and Horonai units of the valcanic area, and the Tonbetsu, southern Okhotsk and northern Okhotsk units of the placer area (Fig. 4).

Daisetsu and Akan "unit provinces."—There are many exhalation and spring ore deposits (UENO and IGARASHI: 1957, UMEMOTO et al.: 1956) in the Daisetsu unit consisting of the Daisetsu and the Tokachi volcanic groups and in the Shiretoko unit along the Akan-Shiretoko volcanic zone. It is considered that they belong to the Kurile volcanic metallogenetic province in a general sense. Some bedded sulphur ore deposits are connected with the activity of the recent volcanoes; they consist of one or more sorts of sublimated, disseminated, precipitated and molten sulphur (YAMAGUCHI: 1953). Ore deposits of the Akan-Io mine, one of the largest sulphur deposits in Japan, lie in a basin-shaped explosive crater and produce various sorts of ore with some iron sulphides accompanying. The Shiretoko-Io mine have worked the large-scale flows of molten sulphur though a certain amount of such sulphur is also formed in other volcanoes. Silica minerals as alteration products of the sulphur ore deposits are mostly cristobalite or opal, such as have not been found from the Tertiary hydrothermal alteration zones excepting one occurrence in the Seta kaolin ore deposits. There are limonite ore beds in the sides of the volcanic bodies, for example at the Nippo, Rausu, and Nittetsu-Tokachi mines; they seem to have been derived from mineral springs. Jarosite is often contained in the limonite ore deposits; examples are known in the Utoro and Tokachi mines. Attention is called to the occurrence of the manganese wad ore deposits of the Akan, Tokachi and Asahidake volcanoes because the deposits of the Akan, Tokachi and Asahidake volcanoes because the deposits seem to lie on the tectonic zones of the Tokoro and the Hidaka manganese metallogenetic "unit province."

Bihoro and Horonai "unit provinces."—There are many small-scale limonit ore deposits in the marginal zone of the level areas formed from pyroclastic ejecta or on the comparatively older terrace areas along the shore of the Okhotsk Sea. As these deposits lie distant from those near the recent volcanoes above mentioned, the Bihoro and Horonai "unit provinces" are established tentatively.

Tonbetsu "unit province".—Placer chrome ore deposits which usually contain platinum are distributed within the drainage area of the Tonbetsu river on the western side of northeastern Hokkaido (BAMBA: 1958, SUZUKI: 1950); it is considered that they originated from chromite and iridosmine grains scattered in the ultrabasic rocks (SUZUKI: 1952). On account of the common feature of the origin of those deposits this unit is established as a part of the placer province in the central N-S zone of Hokkaido.

Northern Okhotsk and southern Okhotsk "unit provinces."—Widely lying placer ore beds which in the beach, sand dunes and terrace deposits along the shore or the Okhotsk Sea comprise variable mineral assemblages and chemical compositions. Workable subjects are titanium in the northern half and iron in the southern half of the shore deposits. It is regarded that the characters of the placer ores were influenced by the geological circumstances of their direct background, especially by the presence of igneous rocks, and even in the due consideration of the ocean current from north to south. Chrome, platinum and gold in the placer are usually no more than minor constituents, the main ones being ilmenite and magnetite. The ratios of TiO_2 to Fe in weight per cent that have been published after

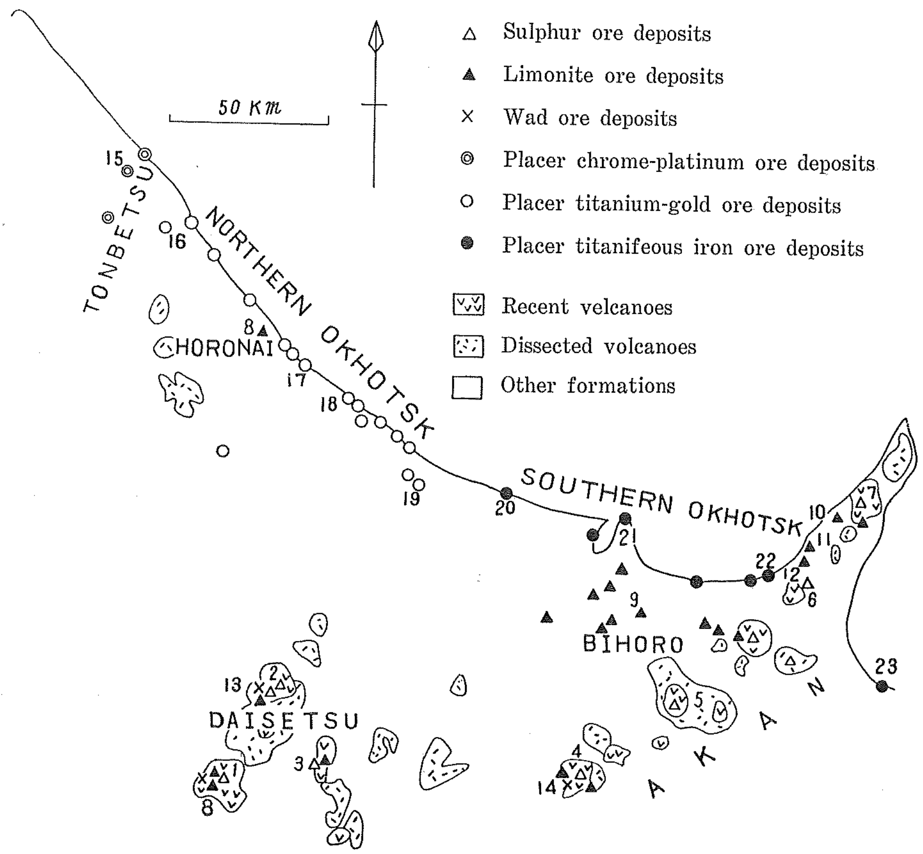

Fig. 4. Sketch map showing "Okhotsk metallogenetic province."

Sulphur ore deposits: 1, Tokachi; 2, Asahidake; 3, Hishinaka-Tokachi; 4, Akan-Io; 5, Atosanupuri; 6, Unabetsu; 7, Shiretoko-Io.

Limonite ore deposits: 8, Horonai-Hokuyu; 9, Bihoro; 10, Utoro; 11, Horodomari; 12, Nippo; 13. Yukomanbetsu.

Wad ore deposits: 14, Akan-Mangan.

Placer chrome-platinum ore deposits: 15, Tonbetsugawa.

Placer titanium-gold ore deposits: 16, Esashi; 17, Sakaeoka; 18, Saruru; 19, Shibun.

Placer titaniferous iron ore deposits: 20, Saroma; 21, Misaki, 22, Shimatokari; 23, Chashikotsu.

assays of the ores (G.S. Japan: 1955, M.I.T.I. Japan: 1955-9) are useful for a distinguishment of the different ore distributions. The value of the ratio is above 0.5 in the northern half, while it is under 0.5 in the southern half. The Yubetsu river is situated on the border line between them. Intensity of magnetism of the northern ores is usually weaker than that of the southern. These data agree with the distribution of older igneous rocks and younger igneous rocks in the background. The older igneous-origin-type ores except for the Shibun ilmenite deposits in Miocene sandstone contain a little chrome, and so they also seem to have all element of the ultrabasic-origin-type placer in the Tonbetsu unit.

Summary and comparison with other metallogenetic provinces

The mineralization of the above mentioned cupriferous iron sulphides, manganiferous iron and manganese ore deposits in Japan seems to be usually divided into the two metallogenetic epochs, Palaeozoic and Mesozoic. The Eastern Hokkaido metallogenetic province which is geographically included in inner Japan belongs to the Mesozoic provinces which mostly are found along the outer zone of the Japanese Islands. Very noteworthy characters are such a Mesozoic system develops as the basement of the Tertiary system in northeastern Hokkaido and that their rocks often constitute the wall-rocks of Tertiary ore deposits.

In the inner zone of northeastern Japan including southeastern Hokkaido. Miocene formations, of which the orders are variable, overlap directly on the Jalaeozoic system (NISHIDA: 1958) except for the Cretaceous plutonic rocks, and most of the Neogene Tertiary ore deposits are scattered in the Miocene series. It has been stated that the ore distribution of the inner zone of northeastern Japan is usually controlled by structural features with N-S and NW-SW directions (AKIBA: 1958, SAKAKIBARA: 1958). According to the geology and geologic structures in this province which is situated in the intersection of the Honshu and Kurile arcs, ore distribution may be controlled by more complicated features than the ore deposits of inner Japan. Kitami province is a part of the so-called green tuff region (MINATO et al.: 1956), but green tuff in a narrow sense develops only along the marginal zone in which the igneous activities seem to have been like those of inner Japan (HUZIOKA: 1958). The spinal Kitami "unit province" is lacking in Neogene Tertiary system except for some plutonic rocks; such a character is also recognized in some parts of the inner zone of southwestern Japan (MIYAHISA: 1958). It has been considered that mineralization in the Neogene Tertiary epoch was connected with effusive igneous activity, for example the gold-silver deposition after the formation of rhyolite (SUZUKI: 1954): But recently intrusive rocks are also regarded as significant in the tectonic and mineralized zones and in mineral assemblages of ores in both the Kitami and inner zone of northwestern Japan (SAKAKIBARA: 1958, TAKEUCHI: 1958, URASIMA: 1958).

There are both a western base metal zone and an eastern (marginal) gold-silver zone in the inner zone of northeastern Japan, (MURAKOSHI and HASHIMOTO: 1956, SEKINE: 1956), but most of the gold-silver ore deposits are distributed within the central part of Kitami mentallogenetic province. There are a few Tertiary base metal ore deposits which produce a large quantity of copper but there are almost no copper sulphosalts, especially arsenic-bearing copper minerals, in this province in comparison with those of the inner zone of northeastern Japan. Distinguishment between gold-silver and base metal ore bodies is usually clearer than in case of the latter. It is also characteristic that rhodochrosite or barite are rarely found in this province, while they abound in southwestern Hokkaido. Mercury ore deposits are almost not recognized from Tertiary ore deposits in inner Japan (YAJIMA: 1958).

It is considered that sulphur ore deposits may be formed by kalcalkalic (tholeiitic) volcanic activity in Japan (MURAOKA: 1953), but no significant deposition in the Diluvian epoch such as is known along other volcanic zones has yet been found in the Akan and Daisetsu "unit provinces."

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