Neogene mineralization in the Kunitomi-Jozankei-Chitose area, Hokkaido, Japan

—with special reference to tectonical setting of the ore deposits—

Kiyoshi HASEGAWA*

Abstract: Most of the Kunitomi-Jozankei-Chitose area is occupied by the Neogene Tertiary system and the Pleistocene series which consist mostly of pyroclastic rocks. They are divided into the Jozankei group of Early Miocene in age, the Furubira Group of ranging from the Middle Miocene to the Late Miocene, the Kucchan Group and the Toyama Group in the Late Miocene, the Nishino Formation of the Pliocene and andesite lava and welded tuff of the Pleistocene.

As volcanic activities after the Early Miocene can be traced at different sites in each sedimentary formation, a tectonic evolution of this area can be reconstructed, on the basis of the shift of sites of the volcanic activity. Thus, this area divided into three tectonic units by the rock facies of the Furubira Group: the Kunitomi unit and the Jozankei unit in which volcanic activities were frequent, and the Yoichi-Kucchan unit in which volcanic activity is less though clastic sediments are prominent.

Many ore deposits of Kuroko, vein type and others occur in this area. Based on the stratigraphy of country rocks, and the K-Ar age of sericitized rocks resulted from the ore mineralization and adularia in the gangue minerals, the mineralization is divided into three stages; the first stage being at deposition of the Furubira Group in Middle Miocene in age, the second stage of the later deposition of the Furubira Group in the late Middle to early Late Miocene, and then the third stage.

The ore deposits of the first mineralized stage are of the typical kuroko which occurred in the area where felsic volcanic rock is prominent around the center of the Kunitomi and the Jozankei units. The ore deposits of the second mineralized stage are of kuroko types with some deposits of vein types in the sites where andesitic volcanic activities took place on the periphery of the Jozankei unit. The ore deposits of the third mineralized stage which are composed of vein type were formed in the middle of the Kunitomi and the Jozankei units, where the uplift was prominent since the Middle Miocene and at the locally uplifted part on the periphery of the Jozankei unit.

INTRODUCTION

The Kunitomi-Jozankei-Chitose area (Fig. 1) is in the southwestern Hokkaido Green Tuff Area, which is regarded as to be a northern extension of the Inner Zone of northeastern Honshu. This area has a wide distribution of the Neogene Tertiary strata mainly comprised

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of pyroclastic rocks. Many types of ore deposits including kurokos, vein types and others are found in these strata. The facts that the types are diverse and that a large amount of metal products is mined, made it as one of famous mining areas in Hokkaido.

Hasegawa and Osanai (1978) described the geology, tectonics and tectonic evolution of the Kunitomi-Jozankei area based on the field geology of the Kunitomi and the Jozankei (MITI, 1969-1974, etc.). Following their work, geological studies had been carried out over the Chitose area, southeast of the Kunitomi-Jozankei Area (MITI, 1979, Hasegawa et al., 1981, 1987). These studies revealed that the same tectonics taken place in the Jozankei area are continuously maintained through the Chitose area. Thus, it is more comprehensive to discuss the tectonics around Jozankei by combining the Kunitomi-Jozankei and the Chitose areas into one.

As for the period of formation of the ore deposits except for that of the kuroko deposits, it has been believed to be a late stage of the Miocene, judging from their country rocks. However, considering the recent works on the dating of the sericitized rocks and adularia related to the mineralization, now requires the revision of the mineralized stage of the ore deposits. Thus, the author attempted to document the characteristics of the sites where ore deposits were formed at each mineralized stage following the tectonic evolution of this area.

I GEOLOGY

Since the Neogene Tertiary stratigraphy, the tectonics and its evolution in the Kunitomi-Jozankei area were repoted by Hasegawa and Osanai (1978), those studies have been extended to cover the area down as far as the Chitose area.
1. Stratigraphy

The Neogene Tertiary system that unconformably covers the basement rocks is divided, in ascending order, into the Jozankei, the Furubira, the Kucchan and the Toyama Groups of the Miocene, and the Nishino Formation of the Pliocene. Brief geologic and petrologic character of these groups will be described following, but among them, the Furubira Group will be described dividing further into four formations in this paper. The Quaternary is composed of andesite lavas, welded tuffs and alluvial deposits (Table 1, Fig. 2).

1.1 Basement rocks

The basement rocks which are mainly composed of alternating beds of sandstone and slate with granodiorite intrusion, are only partially exposed.

1.2 Miocene series

1) Jozankei Group  ... Most of this group are mainly composed of andesite lavas and pyroclas-

<table>
<thead>
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<th>Table 1 Stratigraphical sequence.</th>
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<td>(Ma) Age</td>
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tic rocks, and its upper part consists of rhyolite, welded tuff, mudstone and sandstone.

2) Furubira Group … This group, unconformably covering the Jozankei Group, consists of the Shikaribetsugawa, the Kunitomi, the Yamato and the Kozawa Formations in ascending order.

Shikaribetsugawa Formation: The lower part is composed of conglomerate, sandstone, mudstone and tuff, and the upper part consists of dacite lavas, andesite lavas and their pyroclastic rocks.

Kunitomi Formation: The Kunitomi Formation is partly conformable and partly unconformable with the Shikaribetsugawa Formation. Most of this formation are composed of rhyolite-dacite lavas and their pyroclastic rocks, and the upper part consists of basalt lavas and mudstone.

Yamato Formation: This formation is conformable with the Kunitomi Formation. It is mainly composed of andesite lavas and pyroclastic rocks intercalating with mudstone and sandstone. At the north of Lake Shikotsu, andesitic pyroclastic rocks overlay a thick bed of mudstone which is included in the Yamato Formation (ISHIDA et al., 1980).

Kozawa Formation: This formation is conformable with the Yamato Formation, except for the north part of the Toyoha mine. In the west of Jozankei it is mostly composed of rhyolite lavas and pyroclastic rocks. Around Jozankei it is composed of dacitic pyroclastic rocks, andesite lavas and its pyroclastic rocks.

3) Kucchan Group and Toyama Group … The Kucchan Group is mainly distributed in the west of Jozankei, while the Toyama Group is in the east, unconformably covering the Furubira Group, except around Kucchan and Kunitomi. The Kucchan Group is mainly composed of
andesitic pyroclastic rocks, and the Toyama Group clastic sediments. This two groups are considered to be of the same age, but their relationship is yet to be clarified because they are located in different areas.

1.3 Pliocene series

Nishino Formation: It is unconformable with the lower formations. The basal conglomerate is mainly covered with andesitic-dacitic pyroclastic rocks.

1.4 Quaternary system

The Quaternary includes Pleistocene andesite lavas and welded tuffs, and Holocene floodplain deposits.

2. Intrusive rocks

The Neogene Tertiary system is intruded by such igneous rocks as rhyolite, dacite, andesite, basalt, quartz porphyry and granitic rocks. It is possible to infer the period of intrusion from the age of the country rocks, and the lithologic character of the intrusive rocks (HASEGAWA and OSANAI, 1978). The age determination of the intrusive rocks and stage of intrusion are shown in Table 2 and Figure 3, respectively.

3. Tectonics

Igneous activities were frequent in this area in and after Miocene time. The lithofacies of the Miocene series show that those activities took place regularly in the specific area in each depositional stage of the formation. Therefore, tectonics will be considered mainly on the area in which volcanic activities occurred.

Except for the Jozankei Group, tectonics of the Furubira Group will be described. Since the presence of the Jozankei Group is intermittent, many points are yet to be clarified on the lithofacies and the tectonics, and the ore deposits are more closely connected to the Furubira Group than the Jozankei Group.

<table>
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<th>References</th>
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3.1 Tectono-volcanic division

The Kunitomi-Jozankei-Chitose area is divided into three tectonic units, since different characteristics on lithofacies of the Miocene formations are seen among these units.

The Kunitomi-Jozankei area was once divided into four units; i) the Kunitomi unit, ii) the Jozankei unit, iii) the Yoichi-Kucchan unit, and iv) the east end unit. Except for the east end unit, the units are further divided into subunits (HASEGAWA and OSANAI, 1978).

Since the completion of the geologic sheet map, “Sapporo” of scale 1/200,000 (ISHIDA et al., 1980), the geology of southeastern part of Jozankei has been clarified, and the division has been revised as to divide the east part of Jozankei. It is now called the Toyohiragawa subunit instead of the east end unit, and is included in the Jozankei unit where the Toyama Group is mainly distributed. The Chitose area is included in the Jozankei unit under the temporary name of the Chitose subunit (Fig. 4).

The geological character of each unit be described in the following section.

1) Kunitomi unit... Volcanoes were active over this area in the Miocene with different appearances from place to place. The unit is divided into five subunits (K-1~K-5) by the lines running from northwest to southeast, since the parts of intense volcanic activities in each depositional stage tend to NW-SE direction. The character of each subunit is as follows:

K-1 subunit: The formations between the Shikaribetsugawa Fromation and the Kucchan Group are mainly composed of pyroclastic rocks and clastic sedements.

K-2 subunit: Dacite of the Kunitomi Formation is prominent.

K-3 subunit: The Jozankei Group and conglomerate of the Shikaribetsugawa Formation is distributed, with granitic rock intrusives.

K-4 subunit: Dacite and andesite of the Shikaribetsugawa Formation and dacite of the Kunitomi Formation in the southwestern and northeastern halves, respectively, but the boundary is unclear.
K-5 subunit: Andesite lavas and pyroclastic rocks of the Yamato Formation have extensive distribution.

2) Yoichi–Kucchan unit ... The area contains clastic sediments. The ridgeline, along which pyroclastic rocks of the Yamato Formation is distributed, divides this unit into two subunits (M-1 and M-2).

M-1 subunit: This subunit is characterized by large amount of clastic sediments from the Shikaribetsugawa Formation to the Kucchan Group except for the Kozawa Formation, which is composed of rhyolite lavas and pyroclastic rocks.

M-2 subunit: The formations younger than the Yamato Formation are exposed, where clastic sediments are dominant, except for the Kozawa Formation, which is composed of rhyolite lavas and pyroclastic rocks.

3) Jozankei unit ... The Jozankei unit is divided, by lines also running NW–SE, into J-1~J-6 subunits and the Toyohiragawa and the Chitose subunits which are in the south of the J-6 subunit. In the central part of the unit, i.e. in the J-2~J-5 subunits, the strata which are distributed at the northwestern part are younger as compared with one at the southeastern part. In its center, however, a fault runs NE–SW, causing upheaval of the southeastern part. The lithologic boundaries relatively clear in the southeast of the fault, while they are less clear in the northwest, making it difficult to delineate the lithologic boundaries. Therefore, the lithologic boundaries in the southeastern part were extended to the northwestern part and make the J-2' ~J-5' subunits.

J-1 subunit: The basement rock is located at or near the surface, with the Furubira Group covering it. Pyroclastic rocks are dominant in the formations from the Kunitomi Formation to the Kucchan Group.

J-2 subunit: Pyroclastic rocks of the Kunitomi Formation are composed of this subunit. The J-2' subunit make up by pyroclastic rocks of the Yamato Formation, and a drilling core indicates that pyroclastic rocks and lavas of the Kunitomi Formation and the Shikaribetsugawa Formation are laying under the Yamato Formation.

J-3 subunit: Conglomerate and andesite lavas of the Shikaribetsubawa Formation and pyroclastic rocks of the Kunitomi Formation cover the Jozankei Group. In the J-3' subunit, dacite lavas of the Kunitomi Formation are distributed.

J-4 subunit: Conglomerate and andesite lavas of the Shikaribetsugawa Formation and pyroclastic rocks of the Kunitomi Formation are distributed over the Jozankei Group. A depression took place in this area during the depositional stage of the Shikaribetsugawa Formation. The activity of andesitic volcanics occurred in the depression (Hasegawa and Osanai, 1978). The lavas of the Kunitomi Formation are located in the J-4' subunit, and the drilling cores indicate that andesite lavas of the Shikaribetsugawa Formation underlaid the Kunitomi Formation.

J-5 subunit: The Jozankei Group is distributed in this subunit, and at its north end pyroclastic rocks of the Kozawa Formation overlies the group. The J-5' subunit consists of the Kozawa Formation, composed of pyroclastic rocks, and the Kucchan Group, composed of pyroclastic rocks and clastic sediments.

J-6 subunit: Lavas and pyroclastic rocks of the Yamato Formation are distributed in the entire area. The subunit contains much intrusive rocks.

Toyohiragawa subunit: The Toyama Group consists this subunit.

Chitose subunit: The eastern and western parts of this subunit have different characteristics. The western part contains lavas and pyroclastic rocks of the Yamato Formation, while the
eastern part contains clastic sediments, which should be below the lavas. Western part has much intrusive rocks.

A drilling which was performed at the coast of Lake Shikotsu, about 10 Km east from this area, disclosed no lava, but only indicated that a thin bed of tuffaceous sandstone overlies the thick bed of mudstone which is correlative with the Yamato Formation (SAKO et al., 1977).

4) Tectonics of the Pliocene and the Quaternary … The Nishino Formation of the Pliocene is mainly distributed in the outskirts of the Miocene area, i.e. along the Ishikari Bay and in the plain. It contains andesite-dacite lavas and pyroclastic rocks. This distribution does not correlate with the tectonic division described above. The Pliocene is also distributed at north of the Toyoha mine, almost at the center of the Jozankei unit.

Andesite lavas of the Pleistocene are mainly distributed in the inland, especially in the eastern part of the area. This distribution is not also in harmony with above tectonic division.

3.2 Tectonic evolution

Brief tectonic evolution in the Kunitomi-Jozankei area is considered based on the volcanic activities of the area. Thus, the tectonic evolution of this area is described in this section, concentrating on the depositional stage in and after the Furubira Group period. Volcanic activities at the Middle Miocene began in the depositional stage of the Shikaribetsugawa Formation, with the area gradually spreading outward from the center of the Kunitomi and the Jozankei units. The area between the two units, however, had a little volcanic activity. Sedimentation continued in this area. In the Pliocene and the Pleistocene, volcanic activity occurred in the area mentioned before showing different pattern from those of the Miocene.

1) Depositional stage of the Shikaribetsugawa Formation … The area which had been above sea level began to subside with beginning of sedimentation and volcanic activity of andesite and dacite. Andesite activity was intense in the depression formed in the Jozankei unit, however, it is not yet clarified in other area that depression occurred or not.

2) Depositional stage of the Kunitomi Formation … Volcanisms were most active at the depositional stage of the Furubira Group. The volcanic activity of dacite and basalt occurred in the whole area through two units, except for their central parts (K–3, J–3–5).

Around Kunitomi, the central part of the unit uplifted causing a fracture zone and volcanic activity dominated along the fracture zone (MITI, 1967). This suggests that in the rised unit center, new fractures were formed around it and volcanic activity was accompanied by these fracturs.

Age estimation suggests that the granitic rock distributed in the Toyoha mine intruded during this stage.

3) Depositional stage of the Yamato Formation … In this stage, mainly andesitic volcanic activity occurred in the outskirts of the two units, especially in the area running from north end of the J–6 subunit to the Chitose subunit. In the inner part of those two units, no trace of large-scale volcanic activity is seen, except for the lava distributed in the north of the Toyoha mine.

It is difficult to consider that the volcanic activity spread out beyond the subunit, as has been mentioned about the drilling which was performed at the coast of Lake Shikotsu.

A pyroclastic rocks dominant zone of the Yamato Formation is intruded by dacite, quartz porphyry and granitic rock. They seem to have intruded from the terminal stage of deposition of the Yamato Formation to that of the Kozawa Formation. Volcanism in depositional stage of the Yamato Formation is the most characteristic among the volcanic
Fig. 4  Tectonical division of the Kunitomi–Jozankei–Chitose area and its constituents. (After HASEGAWA and OSANAI, 1978, partly revised)
activities in and after the Miocene, by reason of the intrusion with plutoic rocks followed the volcanic activity.

4) Depositional stage of the Kozawa Formation … Andesite and rhyolite were active in this stage. Andesite is dominant around Jozankei, while rhyolite is in most of the other parts. Andesite is seen where lava and pyroclastic rock of the Yamato Formation are distributed. Rhyolite is distributed in the Yoichi-Kucchan unit and around Otaru and the east of Akaigawa in the Jozankei unit. Although the tectonic movements of this stage are not yet clarified, the setting of the Yoichi basin in the east of Akaigawa (MITI, 1970) indicates that a new sedimentary basin seems to have formed in the area where no sedimentation had taken place, and rhyolitic activity occurred around the basin as well as the Yoichi-Kucchan unit.

5) Depositional stage of the Kucchan Group and the Toyama Group … This area, which mostly uplifted above the sea level after the stage of the Kozawa Formation, sank again and these two groups deposited. The Toyama Group is distributed limitedly in the Toyohiragawa subunit, while the Kucchan Group deposited the west of Jozankei. The reason why the two groups deposited in different areas is yet to be clarified.

The Kucchan Group is widely distributed in the west of Jozankei. The center of the Kunitomi unit uplifted above the sea level (MITI, 1970). The center of the Jozankei unit, as well as the other parts, was overlain with the Kucchan Group. The tectonics of the area covered by the Kucchan Group indicate that its center was the highest part before the Kucchan Group deposited (Fig. 9).

Volcanic activity in the stage of the Kucchan Group is evidenced by some feeder dykes seen in volcanic rock at the east coast of Yoichi (Yamagishi, 1982), suggesting eruption. The other parts indicate no trace of active volcanos.

6) Depositional stage of the Nishino Formation … The Nishino Formation, unlike the other formations dealt with in this paper, unconformably overlies the other formations and is distributed in the area from the Ishikari Bay coast to the plain around Sapporo, as if to divide mountains from the plain. Its location suggests that the tectonic movements which formed a sedimentation basin occurred around Sapporo (MITI, 1974). Although the formation includes lavas and pyroclastic rocks, it is not fully understood where volcanic activities took place. The formation is also located in the inland, in north of the Toyoha mine. Although the sedimentation system is not clarified some depressions could be inferred there.

7) Depositional stage of the Pleistocene andesite lava … The formations described in the above sections show a tendency of which volcanic activities spread outward from the centers of the Kunitomi and the Jozankei units. The Pleistocene andesite lavas, however, was active contrastively in the inner part. After the Nishino Formation deposited, the area uplifted as a whole. Perhaps the Pleistocene vulcanism was active in the rising part.

II MINERALIZATION IN THE KUNITOMI-JOZANKEI-CHITOSE AREA

In this area, the Toyoha (lead and zinc) and the Koryu (gold and silver) mines are in operation at present; the Chitose (gold and silver), the Todoroki (gold and silver), the Ohe (manganese, lead and zinc) and the Inakuraishi (manganese) mines were in operation or prospected until about 1986. In addition, there were famous mines such as the Teine (gold and silver), the Kunitomi (kuroko) and the Otarumatsukura (barite) (Fig. 5).
1. Classification of the ore deposits

Various deposits are located in this area. All of them are classified into four types according to the form of deposits and the main mineral species; (i) typical kuroko, (ii) kuroko type, (iii) vein type and (iv) other deposits. Vein type is classified according to the main ores.

1.1 Typical kuroko deposits

These are the deposits involving stratiform or massive kuroko. The Kunitomi, the Yoichi (Motoyama) and the Meiji deposits are well known in this area, and are called typical kuroko by SATO (1974). All these deposits originated in the Kunitomi Formation.

1.2 Kuroko type deposits

Disseminated and network ore deposits of lead and zinc, and massive barite deposit which located around Akaigawa and Otaru were called kuroko by SUGIMOTO (1959) and MITI (1969). Among of them, the massive barite deposit was called kuroko type deposit by SATO (1974). In this paper, these type ore deposits are classified as kuroko type, because the disseminated and network ore deposit and the massive barite deposit are likely to have close genetic relationship. The Otaramatsukura, the Akaiva, the Yamato, the Hotomi mine, etc. are included in this type. All these deposits are formed in the Yamato Formation.
1.3 Vein type deposits

The vein type deposits are classified into those of lead and zinc (copper), manganese (lead and zinc), and gold and silver according to their main ores. These types of deposits are found in strata below the Kozawa Formation or in the granitic rocks.

1) Lead and zinc (copper) ... The Toyohar mine is a typical large-scale deposit. Many other ore deposits are smaller than that of the Toyohar mine. Among them, the Otoyo deposit is unique in its main ore minerals; luzonite and bismuthinite. Most of these deposits are located mainly in the Jozankei unit.

2) Manganese (lead and zinc) ... The Ohe and the Inakuraishi are typical deposits, whose main ore minerals are rhodochrosite. These deposits involve sulfide minerals, but the amount differs from deposit to deposit.

Though this type of deposit lies mostly in the Kunitomi unit, however, in the Jozankei unit, the Toyohar mine once produced manganese in a little amount.

3) Gold and silver ... The Chitose, the Todboroki and the Koryu are typical deposits. These deposits are generally called “gold bearing quartz vein” as its gangue mineral is quartz. Ore deposit of the Teine mine is different from the typical deposits. The veins of the Teine mine are divided into two groups by the mineral assemblage; one contains Cu-Sb sulphosalts in addition to the minerals found in the typical deposit, the other rich in zincblende and galena (SUGIMOTO, 1952). NISHIWAKI et al. (1971) classified the deposits in this area; the Teine deposit of telluride type, the Todoroiki deposit is a type characterized by sulphosalts with high grade silver, and the Chitose deposit is of argentite type.

1.4 Other deposits ... Besides these deposits mentioned above, there are small manganese oxide and mercury deposits. Three manganese oxide deposits are known. Two deposits of them (the Wakaba and the Kokko) are of stratiform enclosed in the Kunitomi Formation and the Kozawa Formation, the last one (the Inaho) is unclear. One mercury deposit is known, which is disseminated ores formed in the Kunitomi Formation.

1.5 Mineralized zones

In this area, many mineralized zones other than those enclosing known deposits were formed (Fig. 5). Most of them are found out in the formation below the Furubira Group, but some are formed in the Nishino Formation and andesite lava of the Pleistocene. Some mineralized zones indicate metallic ore deposit, others indicate arsenic or sulfur and pyrite deposits, but research on these mineralized zones has not been completed.

2. Classification of the mineralized stage of the ore deposits

The mineralized stage of the ore deposits are examined based on the formation enclosing the deposits and K-Ar age of the altered rocks and adularia in the deposits.

2.1 The country rock of the ore deposits

The typical kuroko deposits is in the Kunitomi Formation, while the kuroko type deposits are in the Yamato Formation. The vein type deposits are embedded in the formations below the Kozawa Formation or in the granitic rocks and the quartz porphyries.

Around some deposits of the vein type, altered rocks are found in younger formation than the formation which contained ore deposits. For instance, in the area from north of the Toyohar mine to east of the Todoroiki mine, altered rocks which are composed of kaolinite,
pyrophyllite, allunite and quartz, occured in strata of the Furubira Group and the Nishino Formation. Moreover, neighboring andesite lavas of the Plistocene become silicified (SAITO et al., 1962). In the Inakuraishi mine, altered rocks of smectite and quartz are found in the Nishino Formation lies on an eastward extension of the Takinosawa vein (HASEGAWA et al., 1969).

These altered rocks cannot be used as age indicators of the ore deposits, because they are different mineral assemblage from the alteration of known ore deposits whose main mineral is sericite and quartz, and they are thought to be alteration products by mineralization of sulfur and pyrite, or by thermal water, and not by known ore deposits. Southeast of the Toyooha mine, alteration involving mainly smectite in the Kucchan Group is considered to be caused by

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<td>porphyry</td>
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<td>112±2</td>
<td>25.3</td>
<td>10.3±0.3</td>
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<td>7-22-4</td>
<td>Yamato rock accompanied of quartz veins in the stored ore</td>
<td>Q,S,K</td>
<td>tuff</td>
<td>1.44</td>
<td>53.6±1.1</td>
<td>31.0</td>
<td>9.56±0.35</td>
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<td></td>
<td>±0.05</td>
<td>53.1±1.2</td>
<td>33.2</td>
<td>9.47±0.35</td>
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The constants used in the age calculation are $\lambda_0=4.962\times10^{-10}$/Y, $\lambda_0=0.581\times10^{-10}$/Y and $^{40}K/K=0.01167$ atm%. Datamination done by Central Research Institute Mitsubishi Metal Corporation.

Q : quartz, S : Sericitic mineral, P : pyrite, C : Carbonate, K : kaolin

<table>
<thead>
<tr>
<th>Deposit Name</th>
<th>Deposit type</th>
<th>K-Ar age(Ma)</th>
<th>Material analyzed</th>
<th>References</th>
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<tr>
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<td>12.5</td>
<td>Mica-bearing clay</td>
<td>This study</td>
</tr>
<tr>
<td>Yoichi</td>
<td>Kuroko</td>
<td>9.7, 11.9</td>
<td>Mica-bearing clay</td>
<td>MAEDA, 1988</td>
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<td>Kuroko type</td>
<td>9.5</td>
<td>Mica-bearing clay</td>
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<td>Pb-Zn-(Cu) vein</td>
<td>10.2</td>
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<td>SAWAI et al, 1989</td>
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<td>Inakuraishi</td>
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<td>Adularia &amp; mica-bearing clay</td>
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<td></td>
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<td>2.8</td>
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<td>Teine</td>
<td>Au-Ag vein</td>
<td>2.3</td>
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<tr>
<td></td>
<td></td>
<td>3.6</td>
<td>Mica-bearing clay</td>
<td></td>
</tr>
</tbody>
</table>

*ISOBE K. (personal communication)
2.2 *K-Ar dating*

The results of the K-Ar dating of altered rocks and adularia in the deposits are shown in Table 4. Among them, those of altered rocks of the Meiji, the Yamato and the Toyohiro mines are carried out newly in this study (Table 3).

The detail of these values on the age has not discussed, because it has been pointed out that altered rock cannot preserve Ar as well as igneous rock, and have minimum age in the alteration (Kaneoka, 1983).

2.3 *Mineralized stage of the ore deposits*

The K-Ar age ranges from 0.56 to 12.5 Ma. These values of the deposits are divided into two groups; deposits which show 9.7~12.5 Ma, and those which show 0.5~4.7 Ma. The former deposits are further divided into the typical kuroko deposits in the Kunitomi Formation and the other deposits in the Yamato Formation.

The mineralized stage of the deposits is divided into three groups based on the stratigraphy of the country rocks and the K-Ar ages; they are the first, second and third mineralized stage.

1) The first mineralized stage ... The typical kuroko deposits in the Meiji, the Yoichi and the Kunitomi mine are included in this stage. The Kunitomi deposit has not yet been dated by the K-Ar method, but the deposit is estimated to be formed at the end of depositional stage of the Kunitomi Formation (Ogura, 1974).

2) The second mineralized stage ... The Yamato mine of kuroko type deposit and the Toyohiro mine of vein type deposit are included in this stage. As the K-Ar age of the quartz porphyry which is the country rock of the Toyohiro deposit indicates 9.5, 10.7 Ma, it is inferred that the deposit was formed immediately after the intrusion of the quartz porphyry, and that the mineralization took place at the latest stage of the Furubira Group.

Only above mentioned two deposits are dated, but similar deposits and mineralized zones are scattered around the both deposits.

The Inatoyo deposit and mineralized zone at the north of the Inatoyo mine (called Tairyouzawa) are considered to be the same stage as the Toyohiro deposit because they are of vein type of which mineral assemblage is similar (Sugimoto, 1965).

Some kuroko type deposits occurred around the Yamato mine such as the Hotomi, the Otarumatsukura and the Taiei mine. From the similarity of their mineral assemblage, and the continuity and similar direction of the mineralized zone which include the ore deposits, these ore deposits are considered to be in the same stage.

3) The third mineralized stage ... Seven vein type deposits of lead and zinc (the Toyoha), manganese (the Ohe and the Inakuraishi) and gold and silver (The Chitoze, the Koryu, the Todoroki and the Teine) were dated. All of those well known large-scale deposits are included in the third mineralized stage.

Based on the following reason, determination of mineralized age by the K-Ar method is accepted with reservation. The ages of these deposits were not obtained from a geological investigation as mentioned before. These observations show that the mineralized age may be before the Pliocene, while the K-Ar age is ranged from the Pliocene to the Plistocene. Therefore, it may safely be said that the age of the third mineralized stage is still unclear in detail, but it can be mentioned that the stage is at least after the depositional stage of the
Furubira Group.

Lead and zinc (copper) vein type deposits were formed in the second and the third mineralized stage. Though only one deposit of each stage has been dated, the difference between them appears to be presence or not of manganese minerals from the mineral assemblage of these deposits. The manganese minerals are absent in the ore deposit of the second mineralized stage.

Above mentioned seven ore deposits are dated. Ore deposits and mineralized zones of similar character are distributed around those seven deposits as follows.

**Lead and zinc (copper) vein type deposit:** The mineralized zones similar to the Toyoha deposit are distributed to the east and northeast of the Toyoha mine which are stretched along the direction of E-W trend, and accompanied lead and zinc with manganese carbonate (MITI, 1972, 1975).

**Manganese (lead and zinc) vein type deposit:** The deposits located south of the Ohe and the Inakuraishi mine can be inferred to be formed in this stage, because they show similar mineral assemblage and their vein trends are virtually parallel to the main and the branch veins of the Ohe and the Inakuraishi mine.

**Gold and silver vein type deposit:** i) It can be estimated that the age of the Eniwa deposit is similar to those of the Chitose and the Koryu deposit, judging from assemblage of the ore minerals and the vein trend. ii) Owing to the feature of abundant in telluride, the Maruyama deposit is considered to be similar to the Teine deposit. The mineral assemblage of the Otoyo mine is similar to those of the lower part of the vein (called Toriyabe-hi) in the Teine mine, judging from the mineral assemblage (SUGIMOTO, 1985). Potentially, these deposits could have formed in the same stage because of their similar mineral assemblage. iii) The Nakanosawa deposit, though manganese mineral is not yet found, is considered to be formed in the same stage as the Todoroki deposit, due to the similarity of the vein trend and the mineral assemblage.

Along with the deposits mentioned above, there are manganese oxide and mercury deposits. Manganese oxide deposits were formed toward the first and second mineralized stage judging from the embedded formation. The formative stage of mercury is unknown.

4. **Ore deposits in each tectonic unit**

From the tectonic view points, the author classified this area into three units and further each unit divided into several subunits as mentioned before. The deposits are distributed mainly in the Kunitomi and the Jozankei units, while there are scarce in the Yoichi-Kucchan unit. Distribution of the ore deposits is in connection with the tectonic division as follows.

4.1 **The Kunitomi unit**

The typical kuroko deposits of the first mineralized stage and manganese vein type deposits of the third mineralized stage are mainly distributed in this unit. The typical kuroko deposits lie in the K-2 and northeastern part of the K-4 subunits where dacite was active in the Kunitomi Formation, and ore deposits of the third mineralized stage are located in the K-3 and southwestern part of the K-4 subunits. The formative stage of lead and zinc vein located in the K-3 subunit is unclear.

4.2 **The Yoichi-Kucchan unit**

Pyroclastic rocks of the Yamato Formation are distributed in the boundary zone of the
M-1 and the M-2 subunits, and lead and zinc mineralization occurred there. This zone adjoins
the J-2 subunit of the Jozankei unit where lead and zinc mineralization took place, and is
regarded as to correspond northwestern extension of the J-2 subunit.

4.3 The Jozankei unit

Many ore deposits are distributed in this unit, such as typical kuroko deposit of the first
mineralized stage, kuroko type deposits and lead and zinc vein type deposits of the second
mineralized stage, and lead and zinc, gold and silver vein type deposits of the third mineralized
stage. The arrangement of the deposits is more complex than that of the Kunitomi unit.

The typical kuroko deposit is found in the J-3' subunit which is dominant of dacite of the
Kunitomi Formation.

Deposits of the second mineralized stage were formed in the Yamato Formation in the
J-6 subunit and its extension toward the northwest of the unit.

Deposits of the third mineralized stage are located in the J-3', the J-4 and the J-5 subunits
in the middle of the unit, and the J-6 and the Chitose subunits in the periphery of the unit. In
the J-3' subunit gold and silver veins are formed, and in the J-4 and the J-5 subunit lead and
zinc veins are formed, while formative stages of some deposits in those subunits such as the
Jozankei and the Toyotomi mine are unknown. In the J-6 and the Chitose subunits, gold and
silver veins are formed mainly, though copper vein also exist in the J-6 subunit.

In the J-2 subunit where a large amount of pyroclastic rocks of the Yamato Formation
are distributed, there are mineralized zones which indicate lead and zinc, and the Kutosan
deposit which indicates gold, silver and copper. Their formative stages are unclear.

Besides the deposits and mineralized zones mentioned above, the mineralized zones of
sulfur, pyrite and arsenic, which were probably formed after metallic deposits, are found mainly
in the center of this unit.

III TECTONICS AS RELATED TO THE FORMATION OF THE ORE DEPOSITS

The relationship between ore deposits of each mineralized stage and the tectonics is
discussed below.

1. The first mineralized stage

The ore deposits of this stage originated in the Kunitomi Formation. The Kunitomi and
the Yoichi are included in the Kunitomi unit and the Meiji in the Jozankei unit, and all of them
are located in the area where dacitic volcanic rock is dominant around the center of the both
units.

Around the Kunitomi mine, the fractured zone striking E-W was generated in the
boundary between the northern uplifting block in the center of the unit and the southern
subsiding block around it, and dacitic activity took place accompanying with deposits in south
of the fractured zone. This movement is understandable fundamentally as a block movement
(MITI, 1969), and the tectonic activity reflects on the bouguer anomaly (OGURA, 1974).

The tectonics on the Yoichi and the Meiji is uncertain in detail, while the bouguer
anomalies around those deposits are the same as the Kunitomi mine (Fig. 6). This fact
demonstrates a likely possibility that the tectonic movements similar to the Kunitomi existed
and was involved in forming deposits.
Fig. 6 Ore deposits of the first mineralized stage plotted on the gravity anomaly map (MITI, 1970).
2. The second mineralized stage

The ore deposits of this stage include the kuroko type deposit of the Yamato mine in the Yamato Formation, and the vein type deposit of the Toyohiro mine of which mineralization are observable in the quartz porphyry, and several deposits are located around these two deposits.

The deposits of this stage were formed on the periphery of the Jozankei unit, i.e. in the northeastern border of the area where the volcanic activity of depositional stage of the Yamato Formation occurred (Fig. 7).

The tectonic movements at the stage of deposit formation in this area include the activity of the intrusive rocks in the Yamato Formation and the rhyolitic activity in the Kozawa Formation. The intrusive rocks have already been described. The rhyolite of the depositional stage of the Kozawa Formation was active around the sedimentary basins of this stage.

The deposits around the Yamato mine appear to be located around the sedimentary basin

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Fig. 7 Ore deposits of the second mineralized stage plotted on the map showing the volcanic rocks predominant zone of depositional stage of the Yamato Formation.
at this stage and to be related to the formation of sedimentary basin and rhyolite activity. However, considering the distribution of sedimentary basins in this whole area and lack of sedimentary basins or activity of rhyolite of this stage around the Toyohiro mine, the formation of deposits cannot be related to the volcanic activity of the Kozawa Formation. Therefore, the deposits of this stage seem to be related to the tectonics caused by the activity of the intrusive rocks which occurred following the volcanic activity of the Yamato Formation.

South of the above mentioned area (the Chitose subunit) and the southern margin of the Jozankei unit (the J-2 subunit) are areas where the volcanic activity of the Yamato Formation occurred, and the volcanic rocks were intruded with granitic rocks and quartz porphyries. Deposit which could have possibly correlated to this stage is not found in the Chitose subunit. As voluminous welded tuff of the Pleistocene covers over the west of the Chitose mine, the geology in this stage has not been surveyed in whole extent of this area. The mineralized zones of lead and zinc, and the deposit of gold, silver and copper were discovered in the J-2 subunit, and this subunit has a high probability that ore deposits of this stage will be found.

3. The third mineralized stage

This stage includes the deposits located in the middle parts of the Kunitomi and the Jozankei units and on the periphery of the Jozankei units as mentioned previously. Though ore deposits located in middle of the both units, they are comprised of manganese (lead, zinc) veins in the Kunitomi unit and lead-zinc (copper) and gold-silver veins in the Jozankei unit. The deposits are located on the periphery are gold-silver and copper veins, seen in the Jozankei unit. The relation between the tectonics and the ore deposits will be described by dividing the middle and the periphery of the units.

3.1 Deposits in the middle of the Kunitomi and Jozankei units.

1) Kunitomi unit ... Figure 8 shows the tectonic evolution of this unit. Granitic rocks intruded at the center of uplift part of the unit and mineral deposits were formed around the center. The K-Ar age of the intrusive rocks indicates 6.6, 7.7 and 8.2±3.8 Ma. The center uplifted before the depositional stage of the Kucchan Group, and therefore the Kucchan Group was not deposited there (MITI, 1970), and the K-Ar age indicates that the uplifted part is accompanied with the intrusion of granitic rocks. 

OTAGAKI (1960) suggested that the fracture, which is located around the center of the Shakotan Dome accompanying deposits, was one of the faults at the time of doming. Similar opinion was mentioned by NARITA et al. (1965). HASEGAWA et al. (1969) clarified a half-dome struture in the south of the Ohe mine and suggested that veins were located around it. All these facts exhibit that the formation of deposits can be related to the tectonic uplift of the central portion of the unit.

2) Jozankei unit ... Figure 9 displays the formations overlain by the Kucchan Group and altitude of the latter base plane. While evidence is lacking that the base of the Kucchan Group has sedimented on the same plane, this map does not depict the movable quantity accurately. The map indicates, however, a very high probability that the center of the unit is the most uplifted part continously both before and after the sedimentation of the Kucchan Group. Being a small body, quartz porphyry dikes with same lithologic character as discovered in Jozankei were found in the Toyoha mine (ISHIKAWA, 1969). From the fact it is apparent that intrusive activity took place at the end of the depositional stage of the Furubira Group. All these facts suggest that tectonic uplift movement found in the center of the Jozankei unit is the same as
Fig. 8  Schematic profile of the Kunitomi unit showing its tectonic evolution. (Ore deposits added to HASEGAWA and OSANAI, 1978).

that of the Kunitomi unit.

As to the tectonic control of the Toyoha mine, MIYAJIMA et al. (1976) asserted that depression formed the fracture and ore veins filled up along his fracture. This theory appears to be related to the whole tectonic movements of the Toyoha area, but they considered the time of depression was at the depositional stage of the Shikaribetsugawa Formation, therefore it is difficult to comprehend how this movement was related to the formation of the deposits. Accordingly, the tectonic setting of the Toyoha's veins seems still remains unsolved. On other hand, in the Todoroki mine a reverse fault with upthrust of the southeastern side of the ore deposit is accompanied with ore veins (HASEGAWA et al., 1976). This indicates the ore deposit is dominated by the uplift tectonic movement.

This movement still continued even after the sedimentation of the Kuchan Group. The greatest uplifted part is situated between the Toyoha and the Todoroki mine. The greatest uplifted part streches from north to south and virtually coincides with the location of andesite lava of the Pleistocene, which is not related directly to the Toyoha and the Todoroki deposit.

3.2 Deposits on the periphery of the Jozankei unit

This area contains the Yamato Formation, but scarce stratum overlies and the techniques to determine the tectonic movement after depositional stage of the Yamato Formation are limited.
Fig. 9 Ore deposits of the third mineralized stage plotted on the map showing the basement of the Kucchan Group.

The relation between the tectonics and each deposit indicates that local uplift dominated the fracture in the Teine (Nakamoto et al., 1970), the Koryu and the Chitose (Akiba et al., 1969, Hasegawa et al., 1981) mines. The uplift part in the Chitose mine was corresponding to the vent area of the volcanic rocks of the Yamato Formation or the intruding part of the granitic rock. The time and condition of the uplift has not been made clear.

IV DISCUSSION AND CONCLUSION

On the Neogene mineralization in the Kunitomi-Jozankei-Chitose area, the following conclusion are obtained.

1) In this area, typical kuroko, kuroko type and vein type deposits are distributed. The vein type deposits includes lead-zinc (copper), manganese (lead-zinc) and gold-silver. The mineralization of these ore deposits are divided into three mineralized stages based on the
formation enclosing the ore deposits and the K–Ar date of the sericitized altered rocks and the adularia; the first corresponds to the end of depositional stage of the Kunitomi Formation in the Middle Miocene and the second seems to correspond to the end of depositional stage of the Furubira Group in the late Middle to the early Late Miocene. The third is after the early Late Miocene, but the age has not been estimated.

The relation between ore formation and tectonics is considered from the veiw point of tectonic evolution.

2) The deposit of the first mineralized stage is the typical kuroko. The age of kuroko deposits indicates 11~16 Ma in the Hokuroku area, northeastern Honshu, being the representative kuroko zone in Japan (OHTOMO, 1983). The typical kuroko located in this area seems to have been formed virtually at the same period, and the volcanism in this area is similar to those of the Hokuroku area of basic and acidic rocks. It has been pointed out that the creation of caldera had taken a important role for the formation of kuroko in the Hokuroku area (TAKAHASHI and TANIMURA, 1980, OHTOMO, 1983, HORIKOSHI, 1983). The author made clear in this paper that the deposits seem to be formed near the boundary between the uplifted and subsided parts in this area, although there are no field evidences of calderas. Therefore, the author concludes that the ore deposits in present area are formed at the similar geologic setting as that of the Hokuroku area.

3) At the second mineralized stage, the kuroko type deposits and some of the vein type deposits were formed. The mineralization has occurred related to the igneous activity of depositional stage of the Yamato Formation accompanied with quartz porphyry and granitic rock intrusion on the periphery of the Jozankei unit, although there are no evidences that these igneous rocks played a role of the "ore bringer".

4) The ore deposits which are composed of vein type were formed in the third mineralized stage, and found out in the middle of the Kunitomi and the Jozankei units and on the periphery of the Jozankei unit. The mineralization may have been related to rather the uplift movement than the igneous activity; uplifts of the middle of the both units have been occurred prominentely through the tectonic movement after the Middle Miocene and its movement has effected to form the fractures where ore deposits were settled there, and the ore deposits on the periphery are apparently to be located at the local uplifted parts in that area.

The deposits of manganese, and lead and zinc vein type deposits were formed mainly in the middle of the uplifted units, and gold and silver deposits occurred on the periphery. YAJIMA (1979) showed previously that these veins are in a zonal distribution of metallic ore deposits in the Jozankei unit.

5) Dating of the ore deposits formed in the third mineralized stage shows 0.5~4.7 Ma, but it is doubtful whether deposits were formed at the isotopic age because field evidences gained hitherto are different from those age as mentional before. It is assumed that the deposits of the third mineralized stage may have been formed about at deposition of the Kuchan Group and the mineralization of sulfur and pyrite occurred in and after the Miocene, according to the field evidences. Furthermore, it is not found out in this area that the mineralization of ore deposit was presented in the Quaternary in addition to the similar dated age to the ore deposits in this area such as in the Izu Peninsula (1.4~2.5 Ma. MITI, 1987) and in Hokusatsu district in Kyusyu (4 and about 1~2 Ma. KUBOTA, 1986).

There are some possibilities that some activities such as sulfur and pyrite mineralization and thermal water occurred after the deposition of metallic ores and effected the Ar content of the sericite and adularia. Therefore, the reexamination of formative ages of the ore deposits
are needed.

6) The history of metallic mineralization in this area is divided into three stages. Especially, the author has established independently the second mineralized stage including the kuroko type deposits and some of the vein type deposits heretofore having been treated as the products of the same concurrent time’s mineralization, and separated them from other vein type deposits. Moreover, he has attempted to examine the ore deposits from the view point of tectonic evolution at each mineralized stage.

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The languages used in each paper are indicated in parenthesis with abbreviation as follows. (J) : written in Japanese. (JWE) : written in Japanese with English abstract.


——— (1976) : Mineralization of late Neogene Tertiary to Quaternary period related to the


Ogura, N. (1974) : Geologic structure, igneous activity and mineralization of the Kunitomi


北海道，国富－定山渓－千歳地域の新第三紀鉱化作用
－とくに地質構造と鉱床の関係について－

長谷川 浩*  

要旨

南東北海道クリーンタフ地域に入れる国富－定山渓－千歳地域は金属鉱床が多数分布する地域である。本文では新第三紀中新世以降の地質構造発達史、および鉱床の形成過程を考察し、その上で鉱床の構造支配を構造発達史の上で検討した。

- 地質－ 新第三紀以降の地質は前期中新世の定山渓層群、中期－後期中新世の古平層群、後期中新世の佐知安層群と砥山層群、鮮新世の西野層および第四紀の安山溶岩や凝灰凝灰岩等から成る。このうち、古平層群は下から両別川層、国富層、大和層、小沢層に分けられる。各地層の多くは主に溶岩や火砕岩によって構成されている。古平層群堆積期に火山活動が活発に行われた帯と劣勢である帯が区分される。火山活動が活発に行われた帯を国富単元・定山渓単元、両者に挟まれ活動が劣勢であった帯を余市－倶知安単元と区分した。層群構成地層の岩相から各単元はさらに亜単元に細分化される。地質構造発達史は、構造区分を基に、火山活動が行われた帯の変遷を重点的に組み立てる。古平層群堆積期では、大別的にみる堆積期初期から末期に向かって単元の前進が直進で火山活動が行われる傾向が認められ、西野層と第四紀層の分布は中新世の構造区分と調和しない。

- 鉱床－この地域に分布する鉱床は黒鉱、黒鉱型および鉱脈型に分類した。鉱床形成期は変質岩・水長石のK-Ar年代論と、地質との関係から3期に分けた。K-Ar年代は既存資料の他に今回3資料を追加した。年代値から12.5－9.5Maと4.7－0.5Maの鉱床に分けられ、前者はさらに国富層に胚胎する鉱床と大和層に胚胎する鉱床に2分され、全体として鉱床形成期は3期に分けられる。第1期は黒鉱、第2期は黒鉱型と一部の鉱脈型、第3期は鉱脈型である。第1期は国富層堆積期、第2期は古平層群堆積期末期の形成といえる。第3期の年代値は鮮新世－第四紀を示すが、野外では西野層に鉱化作用が及んでいる証拠がみあたらない。

- 地質構造と鉱床の関係－この地域は国富、定山渓両単元に分布し、余市－倶知安単元には1鉱床分布するに過ぎない。第1期の鉱床が1鉱床であるが、単元中央周辺の国富層堆積期の酸性岩が活動した帯に形成されている。第2期の鉱床は定山渓単元の外縁部に発達する大和層堆積の火山活動が行われた帯に形成されている。第3期の鉱床は国富、定山渓単元の中央部と定山渓単元外縁部の大和層火山岩分布域である。単元中央は倶知安層群堆積期以前に単元中もっとも上昇したと解釈される。単元外縁の地質構造は明確でないが、鉱床はその地帯内の局部的な隆起部に位置している。第3期の鉱床は、上昇運動に関連して形成された鉱床と考えられる。

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