Mineralization Ages of the Inakuraishi and Ohe Ore Deposits, Southwestern Hokkaido, Japan

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Abstract: In the Inakuraishi-Ohe mining district, there are successive mineralizations from the kuroko-type to polymetallic and iron sulfide vein-type deposits. These sequences can be estimated based on the stratigraphic horizons of their host rocks, the extent of the hydrothermal alteration haloes, and the whole-rock K-Ar dating of the alteration zone. The mineralization ages of the Inakuraishi and Ohe polymetallic vein-type deposits were determined by the K-Ar dating on the sericitized host rocks juxtaposed with these veins. The whole-rock K-Ar ages of the sericitized andesitic rocks of the early Miocene Lower Furubira Formation from the Inakuraishi mine were 4.9±0.2 to 2.7±0.2 Ma. On the other hand, the sericitized quartz diorite of probably late Miocene age from the Ohe mine gave the K-Ar age of 3.4±0.3 Ma. This quartz diorite is considered to be related to the mineralizations of the Inakuraishi and Ohe deposits. It is suggested that the mineralizations of the Inakuraishi and Ohe deposits had taken place in late Miocene to Pliocene time after the intrusion of quartz diorite. Especially the main mineralizations of both deposits appear to have occurred in Pliocene time.

Introduction

Recently, the metallogenetic epochs of some kuroko- and vein-type mineralizations in so-called "Green Tuff" region of southwestern Hokkaido have been discussed based on the K-Ar ages of adularia, mica- or mica/montmorillonite mixed-layer mineral-bearing clay, and sericitized rock (MITI, 1979; Maeda and Ito, 1985; Marumo, 1985; Sugaki and Isobe, 1985; Marumo and Sawai, 1986). However, there are not yet sufficient K-Ar ages of mineralization in the region. Thus the K-Ar dating for some intensively altered rocks was attempted to estimate the mineralization ages of the polymetallic vein-type deposits at the Inakuraishi (latitude 43°10'N and longitude 140°37'E) and Ohe (latitude 43°08'N and longitude 140°41'E) mines located at the foot of the Shakotan Peninsula in the region. The aim of this paper is to report the K-Ar ages of sericitized rocks juxtaposed with the Shinsei, Uwaban 4-go, and Taisei veins in the Inakuraishi mine and the Senzai vein in the Ohe mine, and to discuss the mineralization ages of both deposits.

Geologic Setting

The Shakotan Peninsula belongs to the norther extension of the Green Tuff region in the inner belt of Northeast Japan. The Peninsula is covered extensively by Neogene volcanosedimentary sequence, which lies on the basement rocks of pre-Tertiary age and is partly covered by the Quaternary system. The basement rocks are called the Sannai or Riyamunai Formation which is composed chiefly of chert, slate, phylite, and schist, and Late Cretaceous granodiorite (Nemoto, 1942; Saito et al., 1952; MITI, 1985). The Neogene to Quaternary system comprises the Miocene Kagunuma, Lower Furubira, Upper Furubira, Furugawa, and Toyohama Formations, the Pliocene Yobetsu Formation, and the Pliocene to Pleistocene Nozuka Formation in ascending order (MITI, 1985).

The Inakuraishi-Ohe mining district is underlain mainly by the early Miocene Lower Furubira (or Shikaribetsugawa) Formation, the early to middle Miocene Upper Furubira (or Kunitomi) Formation, and Miocene intrusive rocks (Hasegawa and Osanai, 1978; MITI, 1985). The Lower Furubira Formation in the district consists principally of propy-
litized andesite lava and andesitic pyroclastic rocks, and the Upper Furubira Formation comprises chiefly dacitic and rhyolitic pyroclastic rocks. Both Formations strike NW-SE and gently dip northeast, showing a homoclinal structure, except a few foldings developed locally. Quartz diorite and basalt intruded mainly near the anticlinal axes of both Formations (SHINODA et al., 1974). In other words, the axes of the folds and the distribution of the intrusive rocks have similar trend which is again parallel to the main veins of the Inakuraishi and Ohe deposits (Fig. 1). During the Shakotan doming (OHTAGAKI, 1960), the folding and faulting occurred in the district simultaneously with the intrusion of quartz diorite stocks and basalt dikes. Formation of the fracture system which hosts the mineralizations postdates the folding and the intrusion of quartz diorite and basalt. The host rocks at the Inakuraishi mine are mostly those of the Lower Furubira Formation. While those at the Ohe mine are chiefly the quartz diorite and rocks of the Lower and Upper Furubira Formations.

According to HASEGAWA and OSANAI (1978), quartz dioritic rocks distributed in the Kunitomi-Jozankei area are divided into A-, B-, and C-types based on the rock facies. Among them, A- and B-type rocks were emplaced in the Lower Furubira Formation (MITI, 1985) and the Upper Furubira Formation (MITI, 1985), respectively, in the root of the Shakotan Peninsula. The A-type rocks have phenocrysts of biotite, plagioclase, and quartz, and are relatively equigranular rocks. The B-type rocks have phenocrysts of hornblende, plagioclase, quartz, and K-feldspar, and are generally graphitic showing wide variations in the lithofacies. The biotite K-Ar age of the A-type rock taken from the upper reach of the Shikaribetsugawa River and the whole-rock K-Ar age of the B-type one from the upper reach of the Ponshikaribetsugawa River were 7.7 and 6.6 Ma, respectively (HASEGAWA and OSANAI, 1978; HASEGAWA, K., pers. commun.). The hornblende K-Ar age of the hydrothermally altered quartz diorite from -400 meters level, Ohe mine was 8.2 ± 3.8 Ma (MITI, 1985).

The Neogene mineralizations in the Shakotan Peninsula are roughly divided into the following two types: the kuroko-type and vein-type ones. The former is the Yoichi-Motoyama and Kamoenai mineralizations etc. (MMAJ, 1972; KONO et al., 1983; MITI, 1985, etc.), while the latter is the Yoichi-Yunai, Bikuni, Sakazuki, and Hattari Cu-Pb-Zn and the Inakuraishi, Ohe, Taishu, Shikaribetsu, and Furubira Mn-Pb-Zn ones etc. (NARITA et al., 1965; MITI, 1985, etc.).

The Inakuraishi and Ohe ore deposits are...
the polymetallic vein deposits of manganese, zinc, lead, copper, silver, gold, tungsten, and tin etc. (SATO et al., 1980; MAEDA and ITO, 1984). Most of the veins (the Senzai, Manzai, Tonokawa, Momoyo, and Yoshino veins etc.) in the Ohe mine are parallel to each other, striking roughly N60°W and dipping 80°SW (SATO et al., 1980). A main vein, the Mansei vein, in the Inakuraishi mine consists chiefly of the Tsudo, Shinsei, Honko, Nakankoko, and Uwaban 4-go veins. The veins at the mine are divided into N55°W, N80°W, and N75°E systems (INOUE and KANO, 1959). The veins of N55°W system are the Tsudo, Shinsei, Okinauraishi, and Takinosawa ones, and those of N80°W and N75°E systems are the Honko, Nakankoko, and Uwaban 4-go ones, and the Kinsei, Taisei, and Nansei ones, respectively.

According to SATO et al. (1980), four stages of mineralization at the Ohe mine are discriminated on the basis of structure and mineral paragenesis of the veins. Brecciation occurred between stages I and II, and between stages II and III. The veins of stage IV cut across all the earlier veins of stage I to stage III. Stages II and III are the earlier and later stages, respectively, of the main mineralization.

The stages II and III ores from the Inakuraishi and Ohe mines are characterized by quartz-sulfides and rhodochrosite-sulfides assemblages, respectively. But the details of mineral paragenesis for each stage of ore from both mines are different.

In the Inakuraishi-Ohe-Yoichi mining district, there are the Yoichi kuroko-type, Inakuraishi and Ohe polymetallic vein-type, and Kanayamazawa iron sulfide vein-type mineralizations (MITI, 1970).

The host rocks of the Inakuraishi and Ohe deposits have undergone regional propylitic and local vein-related alterations. Especially the rocks of the Kunitomi Formation (MMAJ, 1972) or Upper Furubira Formation (MITI, 1985) in the Ohe mine area has been affected to some extent by the Yoichi kuroko-type alteration (MAEDA and ITO, 1985), because the Yoichi kuroko deposits occur in the upper horizon of the Kunitomi Formation (MMAJ, 1972). The altered rocks found in contact with the Inakuraishi and Ohe deposits are characterized by the quartz-sericite-pyrite assemblage (e.g., INOUE and KANO, 1959; KONO and SATO, 1964; TSUKADA and UNO, 1980).

According to MAEDA and ITO (1985), the alteration haloes related to the kuroko-type mineralization at Yoichi show zonal distribution; that is, from the center outward, the sericite or K-feldspar, chlorite-sericite, mixed-layer clay minerals, kaoline, and smectite zones. The alteration zones related to the Ohe polymetallic vein-type mineralization running N50°W direction cut the kuroko alteration haloes, and are represented by the zoning from the vein outward: the quartz-sericite, quartz-sericite-chlorite, and chlorite-sericite-quartz-albite zones with small amounts of kaoline. The small alteration haloes, 450 m long and 100 m wide in scale, related to the Kanayamazawa iron sulfide vein-type mineralization having N60°E direction again cut the polymetallic vein-type alteration haloes. The Kanayamazawa alteration haloes are distributed zonally from the center to the margin, the diaspore, pyrophyllite, and kaoline zones.

Description of Samples

Sericitized rock from the Shinsei vein, Inakuraishi mine (Sample No. 81082166): The analyzed sample was taken from the footwall rock in contact with the Maehi vein of the Shinsei vein. It is strongly altered light gray andesite which was veined by both the stage II quartz-hematite networks less than 1 mm in width and the stage III rhodochrosite, quartz, pyrite, galena, and sphalerite veinlets less than 4 mm in width. The mineral assemblage is quartz-1M polytype sericite-pyrite.

Adularia-bearing sericitized rock from the Uwaban 4-go vein, Inakuraishi mine (Sample No. 77072914): The sample was collected from the direct foot wall rock of the Uwaban 4-go vein. It is strongly altered light gray andesite breccia containing the stage II quartz-hematite, stage III rhodochrosite, pyrite, galena, and sphalerite veinlets less than 2 mm in width and stage III quartz, pyrite, sphalerite, and galena networks less than 1 mm in width. The mineral assem-
Sericitized rock from the Taisei vein, Inakuraishi mine (Sample No. 78082527): The sample was taken from the footwall rock of manganese oxides vein, 10 to 20 cm in width, which was formed possibly by weathering of manganese carbonates at the outcrop of the Taisei vein. It is strongly altered light gray andesite containing quartz-pyrite-chalcopyrite veinlets and networks less than 5 cm in width. The mineral assemblage is quartz-1M polytype sericite-chlorite-pyrite.

Sericitized rock from the Senzai vein, Ohe mine (Sample No. 76040806): The sample was collected from the rock fragment in the Senzai vein. It is bleached quartz diorite which was altered strongly by the stage II quartz-pyrite-sphalerite veinlets less than 1 mm in width and the stage III quartz-sphalerite-pyrite-rhodochrosite veinlets less than 5 mm in width. The mineral assemblage is quartz-1M polytype sericite-pyrite. Locations of the dated samples are shown in Figure 1.

The K-Ar age determination on the sericitized rocks was done by Teledyne Isotopes. The constants used in the age calculation are $\lambda_\beta = 4.962 \times 10^{-10}$/year, $\lambda_\alpha = 0.581 \times 10^{-10}$/year and $^{40}K/K = 0.01167$ atom% (Steiger and Jager, 1977). The error was calculated after the method by Cox and Dalrymple (1967). The results are given in Table 1.

Discussion

In the Inakuraishi-Ohe mining district, there are successive mineralizations from the kuroko-type, through polymetallic vein-type to iron sulfide vein-type deposits. The strata-bound sulfide orebody at the Motoyama deposits, Yoichi kuroko mine occurs between the footwall rhyolite and hanging wall rhyolitic pyroclastic rocks in the upper horizon of the early to middle Miocene Upper Furubira Formation (MMAJ, 1972; MITI, 1985). The Yoichi kuroko-type mineralization, therefore, took place in middle Miocene time. But two whole-rock K-Ar ages for the sericitized rhyolite having quartz-1M polytype sericite-pyrite assemblage in the stockwork orebody are 11.9±0.6 and 9.7±0.6 Ma (Maeda et al., in preparation) which are somewhat younger than the K-Ar ages of 14.2–12.3 Ma for mica- or mica/montmorillonite mixed-layer mineral-bearing clay from the kuroko deposits in southwestern Hokkaido (Marumo and Sawai, 1986). The Ohe vein deposits are considered to be closely related to the quartz diorite both spatially and genetically (Shinoda et al., 1974). The quartz diorite has also been intersected by a bore-hole which was drilled from the deeper part of the Inakuraishi mine area (Inoue and Kano, 1959). The K-Ar age data for the quartz diorite intruding in the Upper Furubira Formation at the Ohe mine area are 8.2±3.8 (MITI, 1985) and 6.6 Ma (Hasegawa and Osanai, 1978). The dated hornblende having the age of 8.2±3.8 Ma is affected to a certain extent by the Ohe vein-related alteration (MITI, 1985). Although the age of 8.2±3.8 Ma has a noticeable error, this age can be interpreted to be between the intrusion age of quartz diorite and the vein-related alteration age. Although Hasegawa and Osanai (1978) did not describe the degree of alteration for the dated quartz diorite, the age data reported by them (6.6 Ma) and by MITI (1985: 8.2±3.8 Ma) and field evidence indicate that the quartz diorite stocks were probably intruded in the Upper Furubira Formation in late Miocene time. The Ohe polymetallic vein-type mineralization were later than the Yoichi kuroko-type one based on the stratigraphic relations of their host rocks and the whole-rock K-Ar dating of the alteration zone. The Kanayamazawa iron sulfide mineralization possibly took place after the Ohe mineralization judging from the extent of the hydrothermal alteration haloes.

The whole-rock K-Ar ages for three sericitized andesitic rocks of the Lower Furubira Formation from the Inakuraishi mine and the sericitized quartz diorite from the Ohe mine are 4.9±0.2 to 2.7±0.2 and 3.4±0.3 Ma, respectively (Table 1). These ages probably indicate the times of the vein-related alterations. Among the sampling sites of the dated altered rocks, the Uwaban 4-go vein in the Inakuraishi mine consists only of the stage III ore, while both stage II and III ores are found in other
Table 1 Whole-rock K–Ar ages for sericitized rocks from the Inakuraishi and Ohe mines, Hokkaido, Japan

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Locality</th>
<th>Material</th>
<th>K (wt.%)</th>
<th>(40^{\text{Ar}}_{\text{rad.}}) (scv/\text{x}10^{-5})</th>
<th>Rad. (40^{\text{Ar}}_{\text{tot.}}) (atomic %)</th>
<th>Isotopic age (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>76040806</td>
<td>-30Cm W4 Senzai vein Ohe mine</td>
<td>Sericitized rock</td>
<td>3.22</td>
<td>0.041</td>
<td>32.4</td>
<td>3.3±0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.23</td>
<td>0.043</td>
<td>29.5</td>
<td>3.4±0.3</td>
</tr>
<tr>
<td>81082166</td>
<td>9L £1,745m Shinsei vein Inakuraishi mine</td>
<td>Sericitized rock</td>
<td>4.37</td>
<td>0.082</td>
<td>45.6</td>
<td>4.8±0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.39</td>
<td>0.083</td>
<td>39.7</td>
<td>4.9±0.2</td>
</tr>
<tr>
<td>78082527</td>
<td>Outcrop Taisel vein Inakuraishi mine</td>
<td>Sericitized rock</td>
<td>1.85</td>
<td>0.020</td>
<td>15.1</td>
<td>2.8±0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.84</td>
<td>0.020</td>
<td>16.7</td>
<td>2.8±0.2</td>
</tr>
<tr>
<td>77072914</td>
<td>OL E670m Uwaban 4-go vein Inakuraishi mine</td>
<td>Adularia-bearing sericitized rock</td>
<td>5.82</td>
<td>0.063</td>
<td>14.1</td>
<td>2.8±0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.82</td>
<td>0.062</td>
<td>14.1</td>
<td>2.7±0.2</td>
</tr>
</tbody>
</table>

sites. Therefore it can be considered that the youngest hydrothermal alteration age (2.7±0.2 Ma) from the Uwaban 4-go vein probably represents the age of stage III mineralization. The older ages for the other sites could be those for earlier stage II mineralization. It is suggested that the mineralizations of the Inakuraishi and Ohe deposits had taken place in late Miocene to Pliocene time after the intrusion of quartz diorite and especially the main mineralizations of both deposits in Pliocene time.

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西南北海道稲倉石・大江両鉱床の鉱化期

前田 寛之

要旨: 稲倉石一大江鉱床地域の鉱化作用には, 鉱床の亜
成層内, 熱水変質帯の産状および鉱化変質帯の全岩 K–
Ar 年代に基づいて, 早期から晚期へ, 黒鉱型, 多金属
鉱脈型および硫化鉱鉱脈型鉱化作用がある。稲倉石・大
江両多金属鉱脈鉱床の鉱化期は, 岩脈絶壁サイト化岩の全
岩 K–Ar 年代から推定した。稲倉石鉱山の前期中新世古
平層下部の絶壁サイト化安定岩質全岩 K–Ar 年
代は4.9±0.2~2.7±0.2 Ma であった。一方, 大江鉱床
のおそらく後期中新世の絶壁サイト化岩を基準に, それ
らは3.4±0.3 Ma であった。この岩脈絶壁作用が稲倉石・大
江両鉱床の関係上関係と考えられる。稲倉石・大江両鉱
化作用はその石英絶壁作用を基絶後期中新世~鮮新世
に, そしてとくにその主鉱化作用は鮮新世に行われたと
推定される。

日本語表記

Bikuni 美谷, Furubira 古平, Furuguawa 古寒川, Hattari 発足, Honko 本坑, Inakuraishi 樫倉石, Jozankei 定
山渓, Kamoenai 神恵内, Kanayamazawa 金山沢, Kyanuma 芽沼, Kinsei 金勢, Kunitomi 樋富, Mansei 万
盛, Manzai 万歳, Momoyo 百代, Nanokono 中の
坑, Nansei 南 災, Nozuka 那 坑, Ohe 大 江,
Okinakuraishi 奥稲倉石, Riyamunai リヤムナイ,
Sakazuki 益, Sannai 銃内, Senzai 千歳, Shakotan 薪丹, Shikaribetsu 孫別, Shinsei 新生, Taisei 太盛, Taishu 太
馬, Takanosawa 田ノ沢, Tonokawa 野川, Toyohama 豊
浜, Yobetsu 椿, Yoichi-Yunai 余市太, Yoichi-Motoyama 余市 元山,
Yoichi-Yunai 余市湯内, Yoshino 吉野。