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K–Ar AGES OF POTTERY STONE FROM TAKEHARA MINE, OKAYAMA PREFECTURE, JAPAN

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ABSTRACT

Pottery stone occurs at Takehara Mine located in the eastern end of Okayama City. The mineral assemblages of ore consist mainly of quartz-sericite and quartz-sericite-albite together with scarce quartz-kaolinite. The deposit is divided into three mineral assemblage zones: namely, a kaolinite zone (quartz-kaolinite $\pm$ albite), a sericite zone (quartz-sericite-albite) and an albite zone (quartz-albite-sericite). The albite and sericite zones comprise most of the deposit. The pottery stone in this mine is formed by hydrothermal alteration of Cretaceous rhyolite. K–Ar dating indicates 72–76 Ma for this deposit, which is the same age as the roseki (pyrophyllite) deposit in the Mitsuishi area of Okayama Prefecture.

Key words: K–Ar age, pottery stone, hydrothermal, sericite

INTRODUCTION

There are many reports about pottery stone deposit sites in Japan: Amakusa, Kumamoto Prefecture; Arita, Saga Prefecture; Izushi, Hyogo Prefecture; Tobe, Ehime Prefecture; and so on (Ueno, 1960; Hamano and Ueno, 1951; Togashi, 1974; Miyaji and Tsuzuki, 1988; Nakagawa, 1994; Nakagawa and Matsuura, 1994). They appear to have been formed by hydrothermal alteration of rhyolite and andesite of Paleogene to Neogene. Mesozoic to Paleogene rhyolites are widely distributed in Okayama Prefecture. The Mitsuishi and Yoshinaga areas in the southeastern part of Okayama Prefecture are well known as the site of roseki (pyrophyllite) deposits. There is similar hydrothermal alteration of rhyolite around Takehara Mine in the eastern end of Okayama City. Small-scale mining is carried on there. The present paper has been briefly reported from the viewpoint of the mineral assemblage, chemical composition and K–Ar dating in Takehara Mine.

GEOLOGY AND ORE DEPOSIT

The Takehara Mine is located about 15 km east of the center of Okayama City in a gentle hilly area near the Seto Inland Sea (Fig. 1). The mine has an area measuring about 300 m in the east-to-west direction by about 180 m in the north-to-south direction on the side of a small mountain 101.4 m in height. There is no detailed report on the geology of

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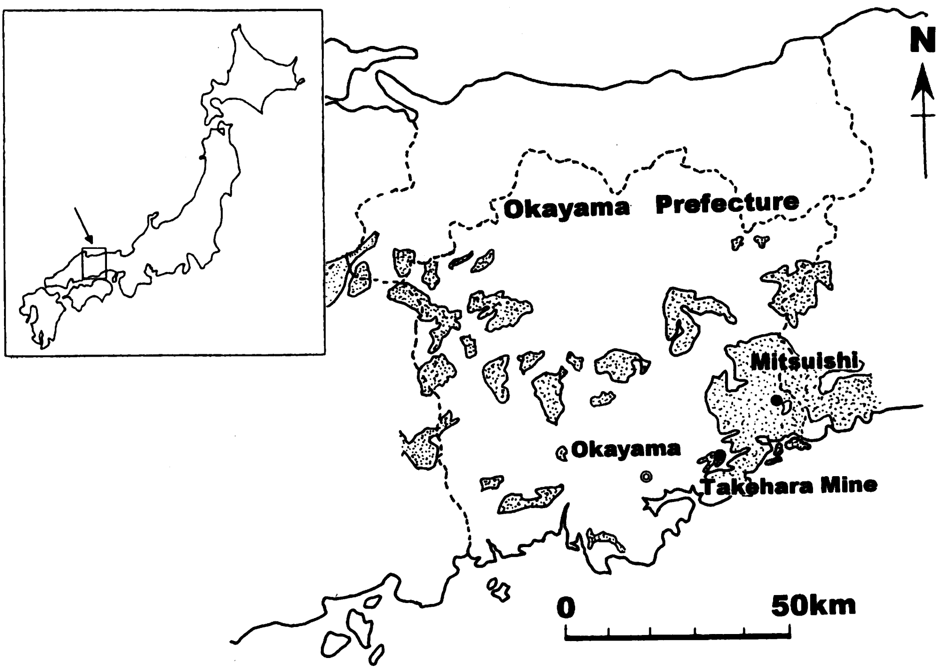

FIG. 1. Location map of the Takehara Mine and distribution of Late Cretaceous ryolitic rocks in Okayama Prefecture.

this area. According to Mitsuno and Sugita (1980) and Ohga and Tanaka (1981), the region is covered with rhyolitic rocks of the Late Cretaceous period (Fig. 1). The same rocks are widely distributed from this area to the Mitsuishi area in southeastern Okayama Prefecture, most of which are tuffaceous. Hydrothermal alteration is often observed in the region of Mitsuishi to Yoshinaga. These regions of alteration have been developed with the same rhyolitic members, and roseki minerals such as pyrophyllite, kaolinite and diaspore have been formed there (Omori, 1966; Fujii, 1979). Granitic rocks are distributed in the southwestern area near the Takehara Mine, and contact metamorphism is partly observed around there. There is a fault in the northeast-to-southwest direction about 30 m away from the southeastern end of the deposit and the alteration is obstructed by the fault. This mine is operated by open cut, and ore is mined at several levels from 50 to 80 m. The pottery stone is shipped at the rate of 1500 t/month as raw materials for tiles, fire bricks and china. The alteration extends throughout the whole of the deposit, and the texture of the original rocks rarely remains in the deposit. The pottery stones from this mine are white to gray or light green in color, and are considerably hard. The microscopic observation shows that the ore consists mostly of aggregates of fine crystals (quartz, sericite and plagioclase under 0.05 mm) and a few phenocrysts (quartz and plagioclase about 0.2 mm).

EXPERIMENT

A total of 92 samples collected from the deposit were powdered by a mortar and pestle and the minerals were identified by X-ray diffraction with monochromatized CuKα radiation. The relative amount of each mineral was determined by the peak intensity compared with the 100 diffraction (3.34 Å) of quartz. Chemical analysis was carried out on selected samples by the wet method. The K–Ar age was determined for six prepared samples under 48–80 mesh by the following procedure. Each sample was divided in two, one for potassium analysis and the other for argon isotopic analysis. The potassium content was determined in duplicate by flame photometry using a Cs buffer solution. Argon was analyzed on a 15-cm radius sector-type mass spectrometer with a single collector by an isotopic dilution method using an argon 38 spike. The decay constants and isotopic abundance ratio used in the age calculations were referred to those by Steiger and Jager (1977). Details of the analytical and instrumental procedures for this system have been described by Nagao and Itaya (1988).

RESULTS AND DISCUSSION

X-ray diffraction and mineral assemblage

The minerals identified from the ores were quartz, sericite, kaolinite, albite (plagioclase may have albite composition by chemical analysis and X-ray diffraction; Bambauer et al., 1967) and montmorillonite. The mineral assemblages are generally classifiable into 3 groups: namely, quartz-kaolinite-sericite $\pm$ albite, quartz-sericite $\pm$ albite and quartz-albite-sericite. The assemblages of quartz-sericite and quartz-albite-sericite were dominant in the deposit. Figure 2 shows the distribution of the relative amounts of kaolinite, sericite and albite estimated by X-ray diffraction. The amount of kaolinite is not abundant and the occurrence is limited to a small area in the southeastern part of the deposit. The relative abundance of sericite increases from the center to the northern part of the deposit, and decreases in the western and southern part of it. The crystallinity of sericite is fairly good. Albite increases from the center to the western part of the deposit. Quartz occurs abundantly everywhere in the deposit. The deposit is roughly divided into three zones in which each of kaolinite (A), sericite (B) and albite (C) is characteristically included. Figure 3 shows representative X-ray diffraction patterns of the sample in respective zones. As mentioned above, sericite and albite ores occupy in the main part of the deposit. In the pottery stone deposits of Japan, plagioclase generally occurs in the outermost part of an alteration zone (Togashi, 1972; Nakagawa and Matsuura, 1994). It is rare for plagioclase to occupy the main part of the deposit as in the case of the Takehara Mine. There is a similar mineral assemblage in the Miyama Mine (Sudo, 1986) in Nagano Prefecture.

Chemical composition

Representative analyses of the major elements from respective zones (Fig. 2; a, b, c) are shown in Table 1. The kaolinite zone (a) is rich in Al_2O_3, while on the other hand SiO_2 is abundant in the sericite zone (b) and albite zone (b). The Al_2O_3 content of one sample from the kaolinite zone (b) is 33.95 wt%. The SiO_2 content is 74.42 wt% and 80.81 wt% in the sericite zone (b) and albite zone (c), respectively. The sericite and albite zones are considerably rich in alkali elements. The K_2O content is 4.43 wt% in the sericite zone while

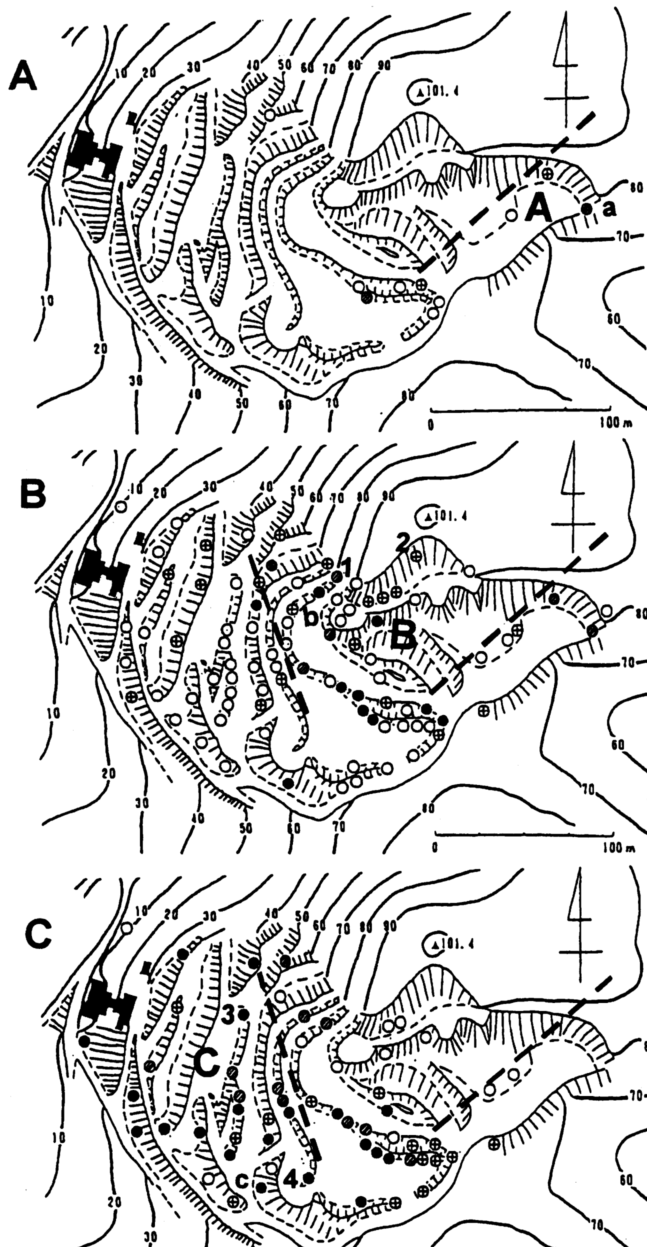

FIG. 2. Distribution of kaolinite, sericite and albite and respective zones. A: kaolinite (zone), B: sericite (zone), C: albite (zone). Symbols show the relative amount of each mineral by comparison with the diffraction intensity of quartz. Numbers following symbols show the ratio of each mineral compared to the 3.4 Å peak intensity of quartz equalling 100. The diffraction peak applicable to each mineral is as follows: 7.2 Å for kaolinite, 10.0 Å for sericite and 3.19 Å for albite. ●: more than 30, ◍: 30–20, ⊕: 20–10, ○: less than 10. a–c; sampling point for chemical analysis. 1–4; sampling point for K–Ar dating.

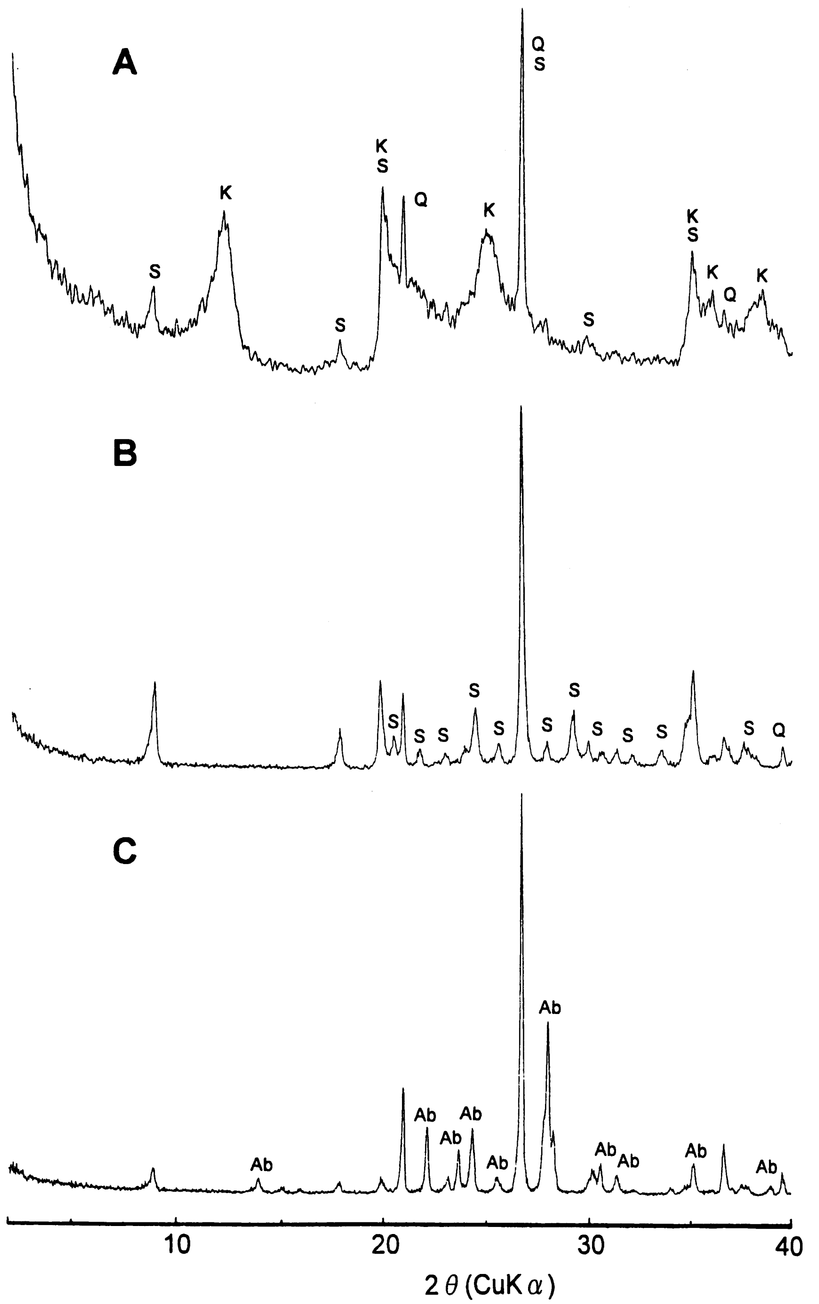

FIG. 3. Representative X-ray diffraction patterns of the pottery stone from each zone. A: kaolinite zone, B: sericite zone, and C: albite zone. Q: quartz, K: kaolinite, S: sericite, Ab: albite.

the Na_2O content is 3.74 wt% in the albite zone.

Dating

The results of K–Ar dating for six samples of the ore (Fig. 2; 1, 2, 3, 4) and host rock are shown in Table 2. The formation age is dated to be 71.9~76.2 Ma for the ore samples from the deposit, while it is dated to be 79.6~83.7 Ma for the host rock. The results of the dating show that magmatic events and hydrothermal alteration occurred in the late Cretaceous period. The findings of the ages for this mine are shown in the figure from Kitagawa et al. (1988) (Figure 4). The formation age of roseki in the Mitsuishi area (Tsuchihashi and Yagi Mines) is dated to be 69~80 Ma (unpublished data and Hongu et al., 2000), and the age for Takehara Mine is in the middle of this period. Therefore, the formation age for the pottery stone of Takehara Mine would be the same age as the hydrothermal alteration of roseki deposits in the Mitsuishi area.

TABLE 1. Chemical analyses of pottery stone ores and rhyolite (host rock) from Takehara Mine

	a	b	c	R
SiO_2	47.47	74.42	80.81	70.60
TiO_2	0.48	0.13	0.08	0.22
Al_2O_3	33.95	17.66	12.11	17.13
Fe_2O_3	2.43	0.23	0.14	0.79
FeO	0.22	0.41	0.11	0.32
MnO	0.03	0.01	0.01	0.01
MgO	0.23	0.12	0.07	0.25
CaO	0.04	0.18	0.02	1.27
Na_2O	0.45	0.10	3.74	3.22
K_2O	1.67	4.43	0.85	4.09
$H_2O(-)$	10.18	1.95	0.44	0.71
$H_2O(+)$	3.02	0.48	0.70	1.56
Total	100.17	100.12	99.08	100.17

a; kaolin zone (K, Q), b; sericite zone (Q, S), c; albite zone (Q, Ab, S), R; Rhyolite (host rock).

TABLE 2. K–Ar ages of pottery stone ores and rhyolite (host rock) from Takehara Mine

Sample	K–Ar age (Ma)	K (wt%)	$_{RAD}{}^{40}Ar$ (10^{-8} ccSTP/g)	$_{AIR}Ar$ (%)
1. S-Q	72.4 ± 1.6	7.72	2213 ± 22	0.9
2. Q-S	76.2 ± 1.7	3.17	957.6 ± 9.5	3.4
3. Q-S-Ab	71.9 ± 1.6	3.29	936.9 ± 9.6	2.6
4. Q-S-Ab	74.3 ± 1.6	2.39	703.5 ± 7.3	4.3
rhyolite (host rock)	79.6 ± 2.5	3.83	1209 ± 30	2.8
rhyolite (host rock)	83.7 ± 1.8	3.52	1170 ± 12	3.1

S; sericite, Q; quartz, Ab; albite.

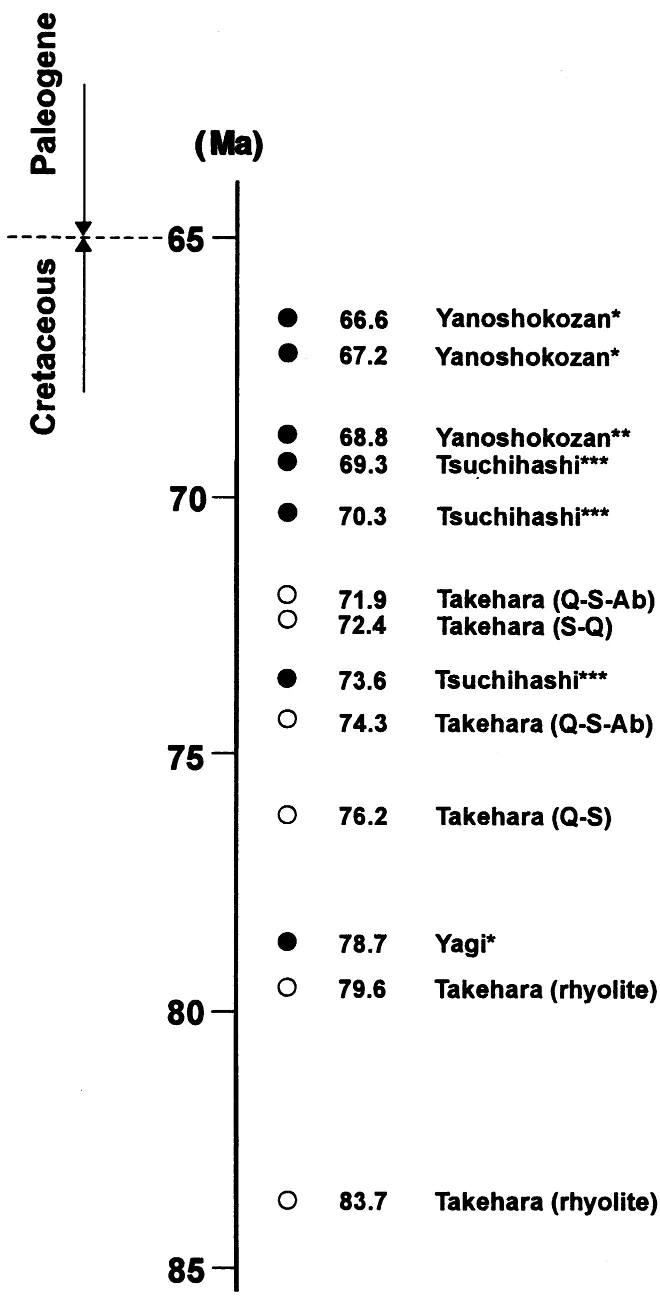

FIG. 4. K–Ar ages (Ma) of sericite-bearing ores in chronological order. *Shibata and Fuji (1971), **Kitagawa et al. (1988), ***unpublished data. Open circle: present study, solid circle: other data. Q: quartz, S: sericite, Ab: albite.

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