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Unpublished K-Ar dates measured in the geochronology laboratory of Yamagata University—Rocks from Omoshiroyama and Gantoyama on the Yamagata-Miyagi prefectural border

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Abstract

This report presents K-Ar dating results of volcanic rocks from Omoshiroyama and Gantoyama on the prefectural boundary separating Yamagata and Miyagi Prefectures, as measured at the geochronology laboratory of Yamagata University. The K-Ar date of a basaltic rock from Omoshiroyama is 1.54 ± 0.15 Ma, indicating contemporaneous volcanic activities for Omoshiroyama and Banji-iwa Volcanic Rocks. The K-Ar date of a rock from Gantoyama Summit Lava is 0.52 ± 0.06 Ma, indicating that volcanic activity of Gantoyama started from ca. 0.5 Ma.

Introduction

The geochronology laboratory of Yamagata University has applied K-Ar dating for rocks from Quaternary volcanoes in northeastern Japan to ascertain the spatiotemporal distribution of volcanic activity in the region. These projects were undertaken earlier by graduate and undergraduate students of former faculty members: Prof. Nobuo Takaoka, Prof. Kazuo Saito, and the late Dr. Kazuya Fukunaga. Measured K-Ar dates were summarized in their theses. Some have been published (e.g. Zaozan, Takaoka et al., 1989; Murayama-Hayama, Saito and Kamei, 1995; Shiratakayama, Ishii and Saito, 1997; Myojinyama, Iwata and Takaoka, 2019; Nanatsumori, Iwata et al., 2019). Nevertheless, few K-Ar dates have been published.

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Similarly to earlier reports, this report presents unpublished K-Ar dates measured at Yamagata University: K-Ar dates from Omoshiroyama and Gantoyama (a.k.a. Gandosan) on the prefectural boundary separating Yamagata and Miyagi.

Omoshiroyama and Gantoyama are situated between Funagata Volcano in the north and Zao Volcano in the south (Figure 1). Amano (1980) designated Banji-iwa Volcanics as volcanic materials distributed in the area including Omoshiroyama, Daitodake, Banji-iwa, Kamurodake and Gantoyama (Happodaira). The Banji-iwa Volcanics was named for a Banji-iwa, huge cliff comprising tuff breccia - lapilli tuff. The Banji-iwa is located in the central part of volcanic material distribution. Ozawa et al. (1987) grouped Ganto-Kamuro Volcano, which includes volcanoes from Omoshiroyama,

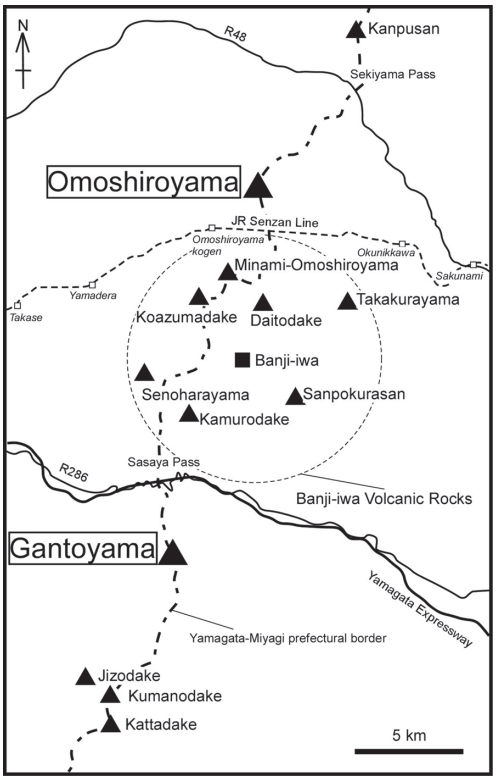

Figure 1. Locations of Omoshiroyama, Gantoyama, and major neighboring summits (solid triangles) near the Yamagata – Miyagi prefectural border (dash-dot line). A solid square indicates the place of Banji-iwa. The broken circle surrounds the area of the Banji-iwa Volcanic Rocks (Yamamoto and Ishikawa, 2006).

Daitodake, Kamurodake, to Gantoyama. Yamamoto and Ishikawa (2006) refined Banji-iwa Volcanics (Amano, 1980) to Banji-iwa Volcanic Rocks (Figure 1). Yamamoto and Ishikawa (2006) excluded Omoshiroyama and Gantoyama from Banji-iwa Volcanics because geographical features of Omoshiroyama and Gantoyama are isolated by surrounding basement rocks. Honda and Tamiya (2016) described Northern Zao Volcanoes as including Omoshiroyama, Minami-Omoshiroyama, Koazumadake, Daitodake, Itodake, Senoharayama, Yamagata-Kamurodake, Sendai-Kamurodake, and Gantoyama. Honda and Tamiya (2016) estimated the active volcanic period of the Northern Zao volcanoes excluding Gantoyama as almost identical because the degrees of mountain form dissections are similar, with no major differences among the chemical compositions of volcanic rock from those volcanoes. Only the published K-Ar date of 1.67 ± 0.08 Ma (KW012; Mimura, 2001) have been reported for a rock from Kamurodake in the Banji-iwa Volcanic Rocks.

The K-Ar dating experiments for the Omoshiroyama and Gantoyama samples are parts of two graduate research projects by Numakunai (1994MS) and Ishii (1998MS) supervised by one of the authors: KS. Compilation and recalculation of K-Ar dates in those papers by Numakunai (1994MS) and Ishii (1998MS) were done by one of the authors: NI. Quoted dates are valuable for the volcano grouping north of the Zao volcanoes.

K-Ar dating

Omoshiroyama is a stratovolcano with the summit locate at N38° 20′ 55.20″, E 140° 31′ 20.49″ (Figure 2). No detailed geological map of the Omoshiroyama area has been reported, nor has the K-Ar age of the Omoshiroyama been reported.

Two rock samples of Omoshiroyama (OM-1 and OM-2) were selected for K-Ar dating. They are rolling stones that had fallen from neighboring places which were collected at the top of different mountain streams on the western side of Omoshiroyama. Sampling positions for OM-1 and OM-2 were, respectively, N38° 20′ 33.60″, E140° 31′ 12.72″ and N38° 21′ 2.60″, E140° 30′ 52.70″. Rock types of both OM-1 and OM-2 are basalt, but no detailed information was reported by Ishii (1998MS). The longitude and latitude are in the Japan Geodetic Datum 2000 (JGD2000).

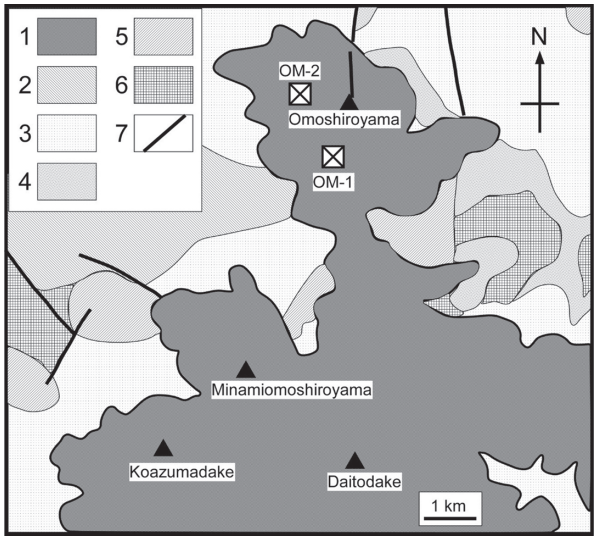

Figure 2. Simplified geological map of Omoshiroyama and southerly area (quoted from Ozawa et al., 1987) and sampling locations of OM-1 and OM-2: 1, Ganto-Kamuro Volcano (Late Pliocene-Early Pleistocene); 2, Dacite tuff, lapilli tuff and welded tuff (Late Miocene-Early Pliocene); 3, Acid pyroclastic rock (Early to Middle Miocene); 4, Andesite lava and pyroclastic rock (Early to Middle Miocene); 5, Rhyolite-dacite lava (Early to Middle Miocene); 6, Granodiorite and Granite (Mid-Cretaceous to Late Cretaceous); 7, fault.

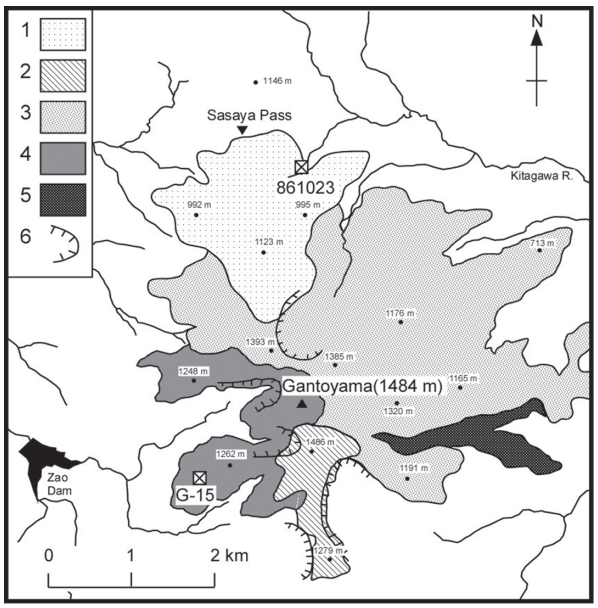

Figure 3. Simple geological map of Gantoyama area (modified after Minamidade, 1991MS) and sampling position for K – Ar dating: 1, Hatchodaira Lava; 2, Happodaira Lava; 3, Higashi-Gantoyama Lava Group; 4, Gantoyama Summit Lava; 5, Toridosawa welded tuff; 6, cliff.

Gantoyama, also a stratovolcano, has its summit located at N38° 11′ 56.59″, E140° 28′ 38.73″ (Figure 3). Volcanic stratigraphy of the Gantoyama is shown by Minamidate (1991MS). Lava is piled from lower to upper, Gantoyama Summit Lava, Higashi-Gantoyama Lava, Happodaira Lava, and Hatchodaira Lava. The Gantoyama Summit Lava lies just above Toridosawa Welded Tuff. No contact between southern Happodaira Lava and northern Hatchodaira Lava was found in the field (Minamidate, 1991MS).

Takaoka et al. (1988) reported conventional K-Ar dates of 0.43 ± 0.03 Ma (groundmass concentration sample, 861023CM) and 0.37 ± 0.03 Ma (whole rock sample, 861023CM) for a rock from Hatchodaira Lava (861023). Mass fractionation corrected K-Ar dates of 861023 were reported as 0.32 ± 0.05 Ma (groundmass concentration sample) and 0.32 ± 0.11 Ma (whole rock sample) using the following argon isotope ratios in atmospheric components (Takaoka, 1989): $^{40}Ar/^{36}Ar$=295.5 and $^{38}Ar/^{36}Ar$=0.188.

A rock sample of Gantoyama, G-15, was employed for K-Ar dating. The rock belongs to the Gantoyama Summit Lava group. The sampling position of G-15 is N38° 11' 28.05", E140° 27' 47.24"(JGD2000). The G-15 rock type is hypersthene-augite andesite (Numakunai, 1994MS).

To avoid the influence of excess argon in phenocryst, the groundmass concentration was used for K-Ar dating. Rock tips of a sample were crushed and sieved into 0.15 – 0.20 mm (OM-1 and OM-2) or 0.25 – 0.30 mm (G-15) size fractions. These grain samples were washed in water and dried. Phenocryst fragments were separated magnetically from the groundmass fraction. Groundmass fractions of OM-1 and OM-2 were concentrated by liquid separation using a sodium polytungustate (SPT) solution.

Potassium contents of samples were measured using an atomic absorption photometer (Type 208; Hitachi Ltd.) in flame photometer mode. Measurements of unknown and reference samples were taken at the same time. Measured potassium contents of the reference samples (JB-2, JA-2, and JG-1a for OM-1, OM-2 and JB-2, JA-2, and JA-3 for G-15, igneous rock series, Geological Survey of Japan Geochemical Reference samples, Imai et al., 1995) are consistent with the reference values within < 3% relative differences. The relative uncertainty of the potassium content analyses was estimated as 3%.

Abundances of radiogenic ^{40}Ar were measured using isotope dilution method with ^{38}Ar spike (for OM-1 and OM-2) or peak comparison method without ^{38}Ar spike following the procedure (for G-15). With the isotope dilution method, argon isotopes were analyzed using a single-focus sector type mass spectrometer of 15 cm radius and 60° deflection. With the peak comparison method, argon isotopes were analyzed using a single-focus sector type mass spectrometer of 20 cm radius and 90° deflection (Takaoka, 1976). To calculate the amount of radiogenic ^{40}Ar, corrections of mass

discrimination and hot blank were conducted during the argon isotope analyses in both analytical methods.

For K-Ar date calculation, the following constants were used: $\lambda_e = 0.581 \times 10^{-10}$, $\lambda_\beta = 4.962 \times 10^{-10}$, and $^{40}K/K = 0.0001167$ (Steiger and Jäger, 1977). Uncertainty related to the K-Ar date was calculated from the propagation of analytical errors in potassium and radiogenic ^{40}Ar contents (1 sigma level). Mass fractionation correction (e.g. Matsumoto et al., 1989; Takaoka, 1989; Matsumoto and Kobayashi, 1995) was applied for the K-Ar dating result of G-15 in this work and 861023 in Takaoka et al. (1988) to compare both dates, which are calculated using the same atmospheric argon isotope ratios. For this correction, we used the following atmospheric argon ratios: $^{40}Ar/^{36}Ar = 295.5$ and $^{38}Ar/^{36}Ar = 0.187$ (Nier, 1950).

Results and Discussion

The K-Ar dating results of Omoshiroyama (OM-1 and OM-2) are presented in Table 1. Among three argon measurements, only one K-Ar date of 1.54 ± 0.15 Ma was obtained from first run of OM-1. The second run of OM-1 and OM-2 measurements revealed non-significant negative values because of lower $^{40}Ar/^{36}Ar$ ratio relative to that of atmospheric component. A positive value from OM-1 is used for the following discussion.

As described earlier, Mimura (2001) reported a K-Ar of 1.67 ± 0.08 Ma from the Kamurodake in Banji-iwa Volcanic Rocks. K-Ar dates of Omoshiroyama, 1.54 ± 0.15 Ma, overlapped to that of Banji-iwa Volcanic Rocks. This temporal coincidence indicates the contemporaneous nature of volcanic activities between the Omoshiroyama and Banji-iwa Volcanic Rocks.

Table 1 presents K-Ar dating results obtained for Gantoyama. Dates with mass fractionation correction of Gantoyama Summit Lava (G-15) were 0.52 ± 0.06 Ma (weighted average of two Ar measurements). The Gantoyama Summit Lava can be assumed as the lowermost lava layer in the Gantoyama (Minamidate, 1991MS), which indicates that volcanic activity with lava eruption started 0.52 ± 0.06 Ma.

The recalculated date with mass fractionation correction of Hatchodaira Lava (861023, Takaoka et al., 1988) was 0.30 ± 0.01 Ma. The volcanostratigraphic relation between lower Gantoyama Summit Lava and upper Hatchodaira Lava is consistent with K-Ar dates. K-Ar dating results indicate that the volcanic activity of Gantoyama started at ca. 0.5 Ma and continued to at least 0.3 Ma. Dates of Gantoyama rocks differ clearly from dates of Omoshiroyama (1.54 ± 0.15 Ma) and Banji-iwa Volcanic Rocks (1.67 ± 0.08 Ma). This difference supports the concept of separation presented by Yamamoto and Ishikawa (2006); the Gantoyama is isolated from Banji-iwa Volcanic Rocks.

Table 1. K–Ar dating results of rocks from Omoshiroyama and Gantoyama

Sample No.	K (wt. %)	^{36}Ar [1]	$^{38}Ar/^{36}Ar$	$^{40}Ar/^{36}Ar$	$^{40}Ar^{*}$ [2]	A.C. [3] (%)	Date (Ma)	MFC [4]
Omoshiroyama								
OM-1	0.323 ± 0.010	6.385 ± 0.067	-	325.8 ± 3.7	1.93 ± 0.18	91	1.54 ± 0.15	
		6.72 ± 0.25	-	294 ± 11	< 0	>100	< 0	
OM-2	0.323 ± 0.010	15.39 ± 0.45	-	287.4 ± 8.6	< 0	>100	< 0	
Gantoyama								
G-15	0.57 ± 0.02	5.73 ± 0.05	0.187 ± 0.001	312.3 ± 0.7	0.96 ± 0.04	94.6	0.44 ± 0.02	
					0.96 ± 0.19	94.6	0.44 ± 0.08	Yes
	0.57 ± 0.02	5.76 ± 0.07	0.185 ± 0.001	312.9 ± 0.8	1.00 ± 0.05	94.4	0.45 ± 0.03	
					1.37 ± 0.19	92.4	0.62 ± 0.09	Yes
Weighted average of G-15							0.52 ± 0.06	Yes

1) Unit of ^{36}Ar is 10^{-10} cm^3 STP/g (STP means Standard Temperature and Pressure)
2) $^{40}Ar^{*}$ means radiogenic ^{40}Ar. The unit of $^{40}Ar^{*}$ is 10^{-8} cm^3 STP/g
3) A.C., air (non-radiogenic component) contamination ratio
4) MFC, mass fractionation correction

Summary

The K-Ar date of a rock from Omoshiroyama is 1.54 ± 0.15 Ma. This date overlaps to the date of Banji-iwa Volcanic Rocks and indicates the contemporaneous nature of volcanic activities between Omoshiroyama and Banji-iwa Volcanic Rocks. The K-Ar date of a rock from Gantoyama Summit Lava is 0.52 ± 0.06 Ma. K-Ar dates of Gantoyama differ from the date of Banji-iwa Volcanic Rocks. Volcanic eruption of Gantoyama started at ca. 0.5 Ma and continued to at least 0.3 Ma.

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