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K-Ar dates measured in the geochronology laboratory of Yamagata University — Daitodake, Senoharayama, Yamagata Kamurodake, Minamiomoshiroyama, Koazumadake, and some volcanic rocks in the Banji-iwa Volcanic Rocks, northeast Japan arc

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Abstract

This report presents K-Ar dating results found for volcanic rocks from Banji-iwa Volcanic Rocks, as measured at the geochronology laboratory of Yamagata University. Groundmass K-Ar dates of the Banji-iwa Volcanic Rocks were from ca. 2.0 Ma to ca. 1.4 Ma, indicating no major difference between their volcanic stages in the Banji-iwa Volcanic Rocks. K-Ar dates of Daitodake, Senoharayama, Yamagata Kamurodake, Minamiomoshiroyama and Koazumadake are, respectively, ca. 2.0 − 1.4 Ma, ca. 1.8 − 1.6 Ma, ca. 2.0 − 1.6 Ma, ca. 1.6 Ma, and ca. 1.8 Ma. The volcanically active period of the Banji-iwa Volcanic Rocks differs from that of Gantoyama, it is not different from that of Omoshiroyama. The discrepancy and coincidence of dates indicate that the Banji-iwa Volcanic Rocks had no genetic relation with Gantoyama rocks, but they did have a genetic relation with Omoshiroyama rocks.

Introduction

K-Ar dating is invaluable to ascertain the spatiotemporal distribution of Quaternary volcanic activity in northeastern Japan. Moreover, multiple dating of different stratigraphic formations of a target volcano is valuable to construct an evolutional history of the volcano. The geochronology laboratory of Yamagata University has applied K-Ar dating in this manner for rocks from Quaternary volcanoes in northeastern Japan. These projects were undertaken earlier by graduate and undergraduate students of former

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faculty members: Prof. Nobuo Takaoka, Prof. Kazuo Saito, and the late Dr. Kazuya Fukunaga in the 1980s–1990s. 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). Nevertheless, few K-Ar dates have been published. Recently, some of these unpublished K-Ar dates have been presented by one author: NI, for Myojinyama (Iwata and Takaoka, 2019), Nanatsumori (Iwata et al., 2019), and Omoshiroyama and Gantoyama (Iwata et al., 2020). Successive to those earlier reports, this report presents unpublished K-Ar dates measured at Yamagata University: K-Ar dates from Daitodake, Koazumadake, Senoharayama, Yamagata Kamurodake, Banji-iwa and some other rocks in the Banji-iwa Volcanic Rocks, Northeast Honshu arc, Japan.

Banji-iwa Volcanic Rocks are situated between Funagata Volcano in the north and Zao Volcano in the south (Figure 1). They are comparably large to Zao Volcano. 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 were named for Banji-iwa, a huge cliff comprising tuff breccia–lapilli tuff. 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, Daitodake, and 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 Omoshiroyama and Gantoyama are isolated topographically by the surrounding basement rocks. Honda and Tamiya (2016) described Northern Zao Volcanoes as including Omoshiroyama, Minamiomoshiroyama, 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 forming dissections are similar, showing no major differences among lithological characteristics of volcanic rock from those volcanoes. Only the published K-Ar date of 1.67 ± 0.08 Ma (KW012; Mimura, 2001) has been reported for a rock from Kamurodake in the Banji-iwa Volcanic Rocks. Additional geochronological information of the Banji-iwa Volcanic Rocks has been expected to concern the spatiotemporal variation of volcanism in the northeastern Japan arc.

The K-Ar dating experiments for rocks from Banji-iwa Volcanic Rocks, conducted mainly as a graduate research project by Ishii (1998MS), were supervised by one author: KS. Additionally, a groundmass K-Ar date from

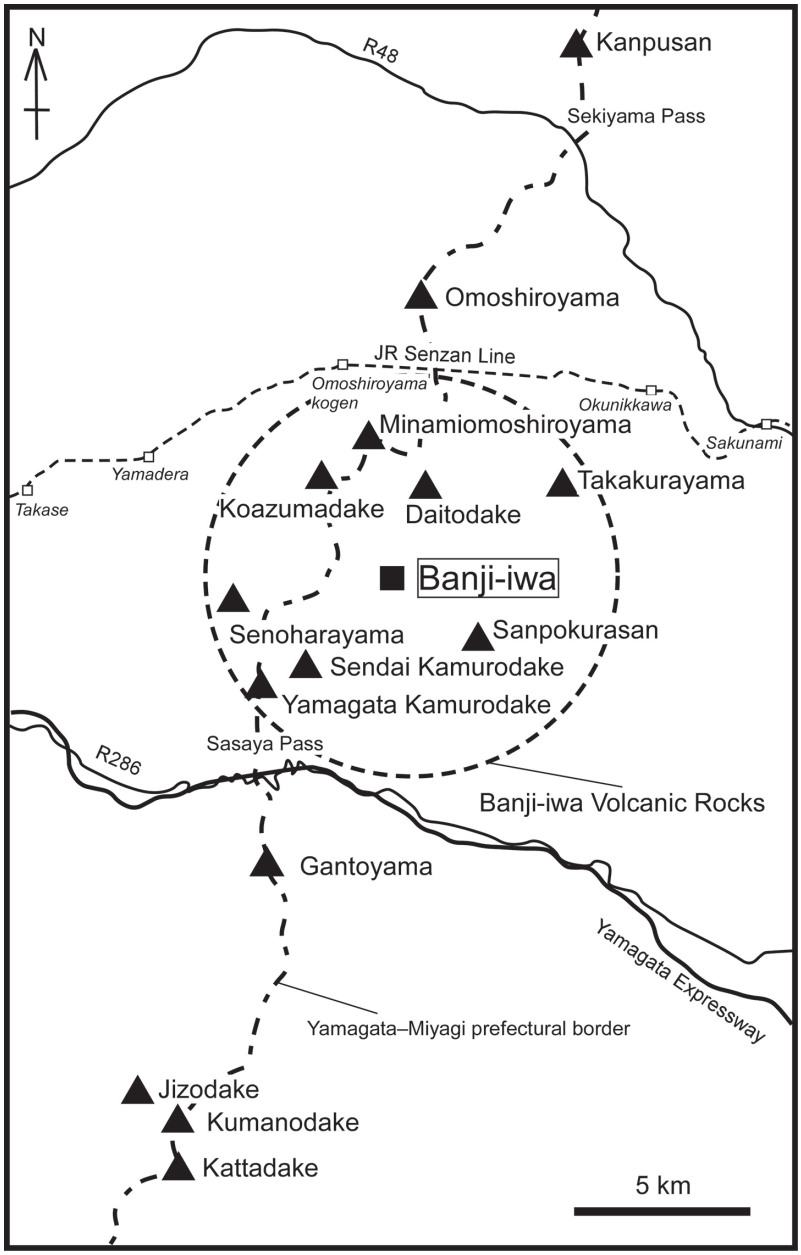

Figure 1. Locations of major summits near the Yamagata–Miyagi prefectural border. The broken circle shows the area of the Banji-iwa Volcanic Rocks (Yamamoto and Ishikawa, 2006).

Banji-iwa Volcanic Rocks was used. It was reported in the appendix section of a graduate research project by Numakunai (1994MS), who was also supervised by KS. Compilation and recalculation of K-Ar dates in those papers by Ishii (1998MS) and Numakunai (1994MS) were done by one author: NI. The quoted dates are valuable for demarcation of volcanoes in the northern area of the Zao volcanoes.

K-Ar dating

Based on findings from a detailed field study, Yamamoto and Ishikawa (2006) summarized the volcanic history in the Banji-iwa Volcanic Rocks as explained below. Volcanic activity of the Banji-iwa Volcanic Rocks is divided into three eruptive stages: Stages I, II and III. Stages I and II are characterized by the formation of subaqueous lava flows, volcaniclastic rocks, and feeder dikes. In addition, Stage I is characterized by the formation of subaqueous lava domes. In contrast, Stage III is characterized by the formation of subaerial composite volcanoes and lava domes. No apparent time gap is presented between Stages I, II and III boundaries.

Yamamoto and Ishikawa (2006) classified the Banji-iwa Volcanic Rocks as described below. Stage I consists of four groups: Kitatarogawa Lava, Futakuchizawa Lava, Yusenkyou Lava, and Anadozawa Volcaniclastic Rocks Member (hereinafter, Volcaniclastic Rocks Member is abbreviated to VRM). Stage II consists of six groups: Banji-iwa VRM, Ainomine VRM, Kabutoiwa VRM, Motoisago VRM, Senninzawa VRM, and Syakkyou VRM. Stage III comprises the following groups: Daitodake Volcanic Rocks (Volcanic Rocks, VR), Senoharayama VR, Yamagata Kamurodake VR, Sendai Kamurodake VR, Nakimushizawa VRM, Takakurayama Lava Dome (Lava Dome, LD), Sanpoukurasan LD, Minamiomoshiroyama LD, Koazumadake LD, and Hinatanagahibazawa VRM.

We measured dates of eighteen specimens from Banji-iwa Volcanic Rocks (Table 1). Figure 2 presents positions of samples, the distribution of stratigraphic formations related to dated samples, and volcanic bodies in the Banji-iwa Volcanic Rocks (Yamamoto and Ishikawa, 2006). Matching between dated specimens and volcanic rock units of the geological map included a little uncertainty because the geological map of Yamamoto and Ishikawa (2006) was not able to be superimposed on the topographic map because the geological map did not show topographical land marks (mountain summits, rivers, or longitude and latitude lines) and because the geological map had an incorrect aspect ratio.

For Stage I, a sample of TR from Kitatarogawa Lava is used for groundmass K-Ar dating. TR is columnar jointed dyke rock. For Stage II, KH-2 and KH-3 from Kabutoiwa VRM are used. KH-2 is columnar jointed dyke rock. KH-3 is columnar jointed lava lying just below tuff breccia. BN, a breccia in the tuff breccia formation of Banji-iwa VRM in Stage II, is also used.

For Stage III, rocks from Daitodake VR, Senoharayama VR and Yamagata Kamurodake VRM, Minamiomoshiroyama LD and Koazumadake LD are used for K-Ar dating.

In Daitodake VR, four samples are used for K-Ar dating: DT-N, DT-21,

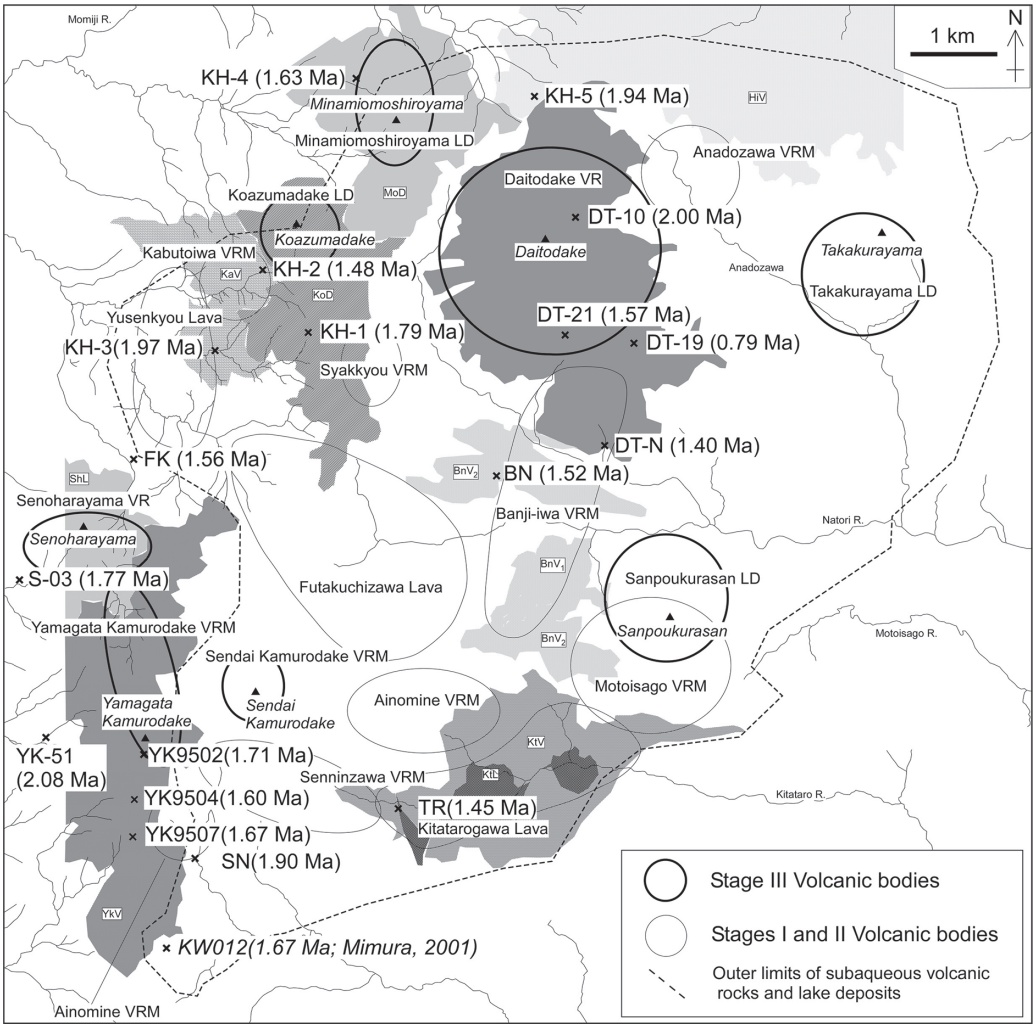

Figure 2. Location of sample (×), distribution of selected formations, and estimated volcanic bodies in the Banji-iwa Volcanic Rocks. Distribution of formation and estimated volcanic bodies were modified from a report by Yamamoto and Ishikawa (2006). Formations are the following: KtV, Kitatarogawa volcanic breccia; KtL, Kitatarogawa lava or dyke; BnV1 and BnV2, Banji-iwa Volcanic Rock Member; YkV, Yamagata Kamurodake VR; ShL, Senoharayama LF; KaV, Kabutoiwa VRM; KoD, Koazumadake LD; MoD, Minamiomoshiroyama LD; and HiV, Hinatanagahibazawa VRM. The eastern extent of HiV and western extent of YkV and ShL are not presented in the geological map in Yamamoto and Ishikawa (2006).

DT-19, and DT-10. Yamamoto and Ishikawa (2006) subdivided the Daitodake VR into nine formations: Shishiuchizawa Lava Flow (Lava Flow, LF), Shiratakizawa LF, Daitodaki LF, Toinosawa LF, Yakichi LF, Tateishizawa Pyroclastic Flow Deposits (Pyroclastic Flow Deposits, PFD), Kobushidaira LF, Azumaogake LF, and Yakichi LD. Shiratakizawa LF, Daitodaki LF,

Table 1 List of samples for K-Ar dating

Sample No.	Latitude (N)	Longitude (E)	Altitude (m)	Type
		Stage I		
Kitatarogawa Lava				
TR	38° 14′ 37.14″	140° 30′ 15.10″	660	two px dacite
		Stage II		
Kabutoiwa VRM				
KH-2	38° 17′ 56.15″	140° 29′ 12.22″	760	two px andesite
KH-3	38° 17′ 26.56″	140° 28′ 49.35″	570	two px andesite
Banji-iwa VRM_2				
BN	38° 16′ 39.75″	140° 31′ 2.29″	700	two px basaltic andesite
		Stage III		
Daitodake VR				
DT-10	38° 18′ 15.77″	140° 31′ 39.26″	1050	two px andesite
DT-19	38° 17′ 28.99″	140° 32′ 6.64″	990	two px andesite
DT-21	38° 17′ 32.26″	140° 31′ 33.35″	850	two px andesite
DT-N	38° 16′ 51.70″	140° 31′ 52.43″	550	two px andesite
KH-5	38° 19′ 0.35″	140° 31′ 19.21″	880	two px andesite
Senoharayama VR				
FK	38° 16′ 46.91″	140° 28′ 10.80″	750	two px andesite
S-03	38° 16′ 1.56″	140° 27′ 18.04″	820	two px basaltic andesite
Yamagata Kamurodake VRM				
YK-51	38° 15′ 4.18″	140° 27′ 30.60″	930	two px andesite
YK9502	38° 14′ 57.31″	140° 28′ 15.44″	1270	two px andesite
YK9504	38° 14′ 40.94″	140° 28′ 11.58″	1220	ol- two px basaltic andesite
YK9507	38° 14′ 26.49″	140° 28′ 10.80″	1140	two px basaltic andesite
SN	38° 14′ 19.39″	140° 28′ 40.31″	790	two px dacite
Minamiomoshiroyama LD				
KH-4	38° 19′ 7.52″	140° 29′ 54.78″	920	two px andesite
Koazumadake LD				
KH-1	38° 17′ 33.29″	140° 29′ 33.38″	1100	two px andesite

Abbreviations: px, pyroxene; ol, olivine

Toinosawa LF, Yakichi LF, Tateishizawa PFD, Kobushidaira LF, Azumaogake LF, and Yakichi LD can be arranged from lower to higher in stratigraphic order. Shishiuchizawa LF situated at the same stage of Tateishizawa PFD below the Kobushidaira LF. These stratigraphic relations are inferred from aerial stereophotographs, not from field observations (Yamamoto and Ishikawa, 2006). Based on the geological map in Yamamoto and Ishikawa (2006), we assumed that DT-N is from Shiratakizawa LF, DT-21 is from Toinosawa LF, DT-19 is from Kobushidaira LF, DT-10 and KH-5 are from Azumaogake LF. Additionally,

we infer that KH-5 belongs to Daitodake VR in this report. KH-5 is two-pyroxene andesite that is interlayered by lower altered andesite and upper tuffaceous rock. The sampling location of KH-5 is near the border of Hinatanagahibazawa VRM and Daitodake VR. Yamamoto and Ishikawa (2006) described Hinatanagahibazawa VRM as consisting of pyroclastic rocks and course-grained tuff that originated from Minamiomoshiroyama. Because KH-5 is andesitic rock, we inferred that KH-5 is from Daitodake VR, not from Hinatanagahibazawa VRM, as Yamamoto and Ishikawa (2006) had supposed.

We infer that S-03 and FK belong to Senoharayama VR for this report: S-03 was collected from the southwestern flank of Senoharayama: FK is columnar jointed two-pyroxene andesite. In the geological map of Yamamoto and Ishikawa (2006), the sampling location of FK is denoted as "?". That location is surrounded by Senoharayama Lava Flow (two-pyroxene andesite), Yusenkyou Lava (two-pyroxene dacite), Futakuchizawa Lava (opx andesite) and the northernmost part of Yamagata Kamurodake VR (two-pyroxene dacite). Because FK is two-pyroxene andesite, we assumed that the most plausible group of FK is the Senoharayama Lava Flow.

Five samples are dated from Yamagata Kamurodake VR. Three of them, YK9502, YK9504, and YK9507 are columnar jointed lava on the southern ridge line of Yamagata Kamurodake. YK-51 is collected from the western flank of Yamagata Kamurodake. SN is collected from columnar jointed lava just on sedimentary rocks at the southeastern flank of Yamagata Kamurodake. Although the sampling location of SN is assumed to be in the area of Anadozawa Formation of Yamamoto and Ishikawa (2006), we classified this sample as part of Yamagata Kamurodake VR because it was collected from lava.

A sample of KH-4 from Minamiomoshiroyama LD has the characteristics of being columnar jointed. A sample of KH-1 from Koazumadake LD was collected from a large boulder on the ridge line between from Koazumadake and the southern 1227.6 m peak.

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 size fractions. These grain samples were washed in water and were then dried. Phenocryst fragments were separated from the groundmass fraction magnetically. In addition, the groundmass fraction was concentrated by heavy liquid separation using a sodium polytungustate (SPT) solution.

Potassium contents of samples were measured using flame photometry with an atomic absorption photometer (Type 208; Hitachi Ltd.) in flame photometer mode. Measurements of unknown and reference samples were taken simultaneously. Measured potassium contents of the reference

samples (JB-2, JA-2, and JG-1a, igneous rock series, Geological Survey of Japan Geochemical Reference samples, Imai et al., 1995) are consistent with 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

Table 2. K-Ar dating results of rocks from Banji-iwa Volcanic rocks

Sample No.	K	$^{40}Ar/^{36}Ar$	$^{40}Ar^{*}$	A.C.	K-Ar date
TR	0.784 ± 0.024	341.8 ± 6.4	4.42 ± 0.61	86.5	1.45 ± 0.21
KH-2	0.397 ± 0.012	370.8 ± 8.4	2.28 ± 0.26	79.7	1.48 ± 0.17
KH-3	0.909 ± 0.027	617 ± 18	6.95 ± 0.44	47.9	1.97 ± 0.14
BN	0.613 ± 0.018	321.0 ± 4.0	3.62 ± 0.57	92.1	1.52 ± 0.24
DT-10(a)	0.703 ± 0.021	509.2 ± 7.0	5.45 ± 0.19	58.0	1.99 ± 0.09
DT-10(b)	0.703 ± 0.021	364.5 ± 6.8	5.46 ± 0.54	81.1	2.00 ± 0.21
			weighted average of DT-10(a) and (b)		2.00 ± 0.08
DT-19	0.895 ± 0.027	313 ± 13	2.73 ± 2.03	94.4	0.79 ± 0.58
DT-21	0.655 ± 0.020	339.5 ± 6.2	4.00 ± 0.57	87.0	1.57 ± 0.23
DT-N(MN)	0.635 ± 0.019	312.2 ± 1.9	3.44 ± 0.40	94.7	1.40 ± 0.17
KH-5	0.717 ± 0.022	371.9 ± 5.0	5.40 ± 0.36	79.5	1.94 ± 0.14
FK	0.337 ± 0.010	319.8 ± 4.7	2.04 ± 0.40	92.4	1.56 ± 0.31
S-03(a)	0.739 ± 0.022	321.9 ± 4.6	4.50 ± 0.79	91.8	1.57 ± 0.28
S-03(b)	0.739 ± 0.022	328.9 ± 4.1	5.50 ± 0.68	89.8	1.92 ± 0.24
			weighted average of S-03(a) and (b)		1.77 ± 0.18
YK-51(a)	0.677 ± 0.020	387.1 ± 4.9	5.43 ± 0.30	76.3	2.07 ± 0.13
YK-51(b)	0.677 ± 0.020	417 ± 11	5.53 ± 0.52	70.9	2.10 ± 0.21
			weighted average of YK-51(a) and (b)		2.08 ± 0.11
YK9502	0.732 ± 0.022	483 ± 17	4.86 ± 0.46	61.2	1.71 ± 0.17
YK9504	0.481 ± 0.014	413 ± 10	2.99 ± 0.26	71.5	1.60 ± 0.15
YK9507	0.522 ± 0.016	467 ± 12	3.39 ± 0.25	63.3	1.67 ± 0.13
SN	0.899 ± 0.027	573 ± 18	6.63 ± 0.48	51.6	1.90 ± 0.15
KH-4	0.723 ± 0.022	503 ± 22	4.57 ± 0.52	58.7	1.63 ± 0.19
KH-1	0.851 ± 0.026	714 ± 40	5.92 ± 0.65	41.4	1.79 ± 0.20

N.B.

1) K stands for potassium content. The unit of K is weight percent.

2) $^{40}Ar^{*}$ denotes radiogenic ^{40}Ar. The unit of $^{40}Ar^{*}$ is 10^{-8} cm^3 STP/g. STP denotes standard temperature and pressure.

3) A.C., air (non-radiogenic component) contamination ratio. The unit of A.C. is %.

4) The K-Ar date unit is Ma.

(MN) K-Ar date of DT-N was measured by Numakunai (1994MS)

method with ^{38}Ar spike. Samples were degassed at 1500℃ in a Mo crucible using a resistance furnace. Extracted gases were purified by two Ti getters with a Zr-Al getter pump. They were then introduced into a mass spectrometer. Argon isotopes were analyzed using a single-focus sector type of a mass spectrometer of 15 cm radius and 60° deflection. To calculate the radiogenic ^{40}Ar amount, corrections of mass discrimination and hot blank were conducted during argon isotope analyses in this analytical method.

For K-Ar date calculation, the following constants were used: $\lambda_e = 0.581 \times 10^{-10}$ year^{-1}, $\lambda_\beta = 4.962 \times 10^{-10}$ year^{-1}, and $^{40}K/K = 0.0001167$ (Steiger and Jäger, 1977). Uncertainty related to the K-Ar date was calculated from propagation of analytical errors in potassium and radiogenic ^{40}Ar contents (1 sigma level).

Results and Discussion

K-Ar dating results are presented in Table 2. Figure 3 depicts the date distribution of each volcanic group.

Four K-Ar dates are presented for volcanic rocks from Stage I and Stage II in this report. KH-3 of Kabutoiwa VRM in Stage II yields the oldest date (1.97 ± 0.14 Ma) in Stage I and Stage II volcanic rocks. For two dyke rocks, dates of TR of Kitatarogawa Lava in Stage I and KH-2 of Kabutoiwa VRM in Stage II are, respectively, 1.45 ± 0.21 and 1.48 ± 0.17 Ma. Younger dates of dyke are reasonable because a dyke must intrude into surrounding formations. The date of BN, a breccia in tuff breccia formation of Banji-iwa VRM in Stage II, is 1.52 ± 0.24 Ma. Providing that the breccia are of essential origin, this date indicates the time of Banji-iwa VRM activity.

Five K-Ar dates from Daitodake VR of Stage III extend from ca. 2.00 Ma to ca. 0.79 Ma. Although DT-19 (0.79 ± 0.58 Ma) reveals apparently youngest dates in the Banji-iwa Volcanic Rocks, we exclude the dates from the following discussion because their inherent uncertainty is too large for date comparison. Four other dates are spread to two groups, older ca. 2.0 Ma (DT-10 and KH-5) and younger ca. 1.5 Ma (DT-21 and DT-N). This result is expected to indicate the presence of at least two eruption phases of volcanic activity in the Daitodake VR. Based on the report by Yamamoto and Ishikawa (2006), the subdivision of the Daitodake VR, ca. 2.0 Ma specimen (DT-10 and KH-5) from Azumaogake LF erupted at the penultimate stage of Daitodake volcanism. Discrepancy between the order of K-Ar date and the stratigraphic order of subdivided volcanic formation must be examined in future studies.

For Senoharayama VR of Stage III, two K-Ar dates are obtained: S-3 is 1.77 ± 0.18 Ma; FK is 1.56 ± 0.31 Ma. Dates of Senoharayama VR represent contemporaneous dates of Daitodake VR above and then Yamagata

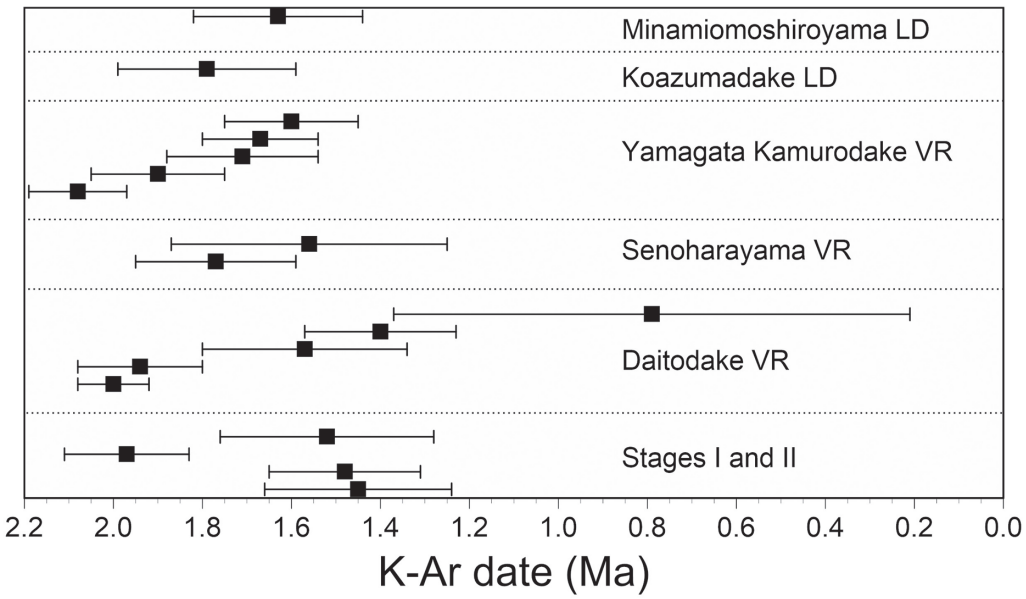

Figure 3 K-Ar date distribution of the Banji-iwa Volcanic Rocks.

Kamurodake VRM.

K-Ar dates from Yamagata Kamurodake VRM of Stage III are divisible into two divisions: older (ca. 2 Ma) and younger (ca. 1.6 Ma). Older dates are obtained from rocks of lower altitude relative to the southern ridge line of Yamagata Kamurodake, SN (790 m) is 1.90 ± 0.15 Ma; YK-51 (930 m) is 2.08 ± 0.11 Ma. The stratigraphic relation between SN and YK-51 remains unclear because their sampling locations are placed respectively east and west of the southern ridge line of the Yamagata Kamurodake. Older dates indicate the presence of earlier volcanic activity of Yamagata Kamurodake. Younger dates assigned to rocks at southern ridge line of Yamagata Kamurodake, YK9502 (1.71 ± 0.17 Ma), YK9504 (1.60 ± 0.15 Ma), and YK9507 (1.67 ± 0.13 Ma). Mimura (2001) reported a similar date for a rock (KW021) from Sasaya Pass, south of Yamagata Kamurodake, 1.67 ± 0.08 Ma. Accordant dates of Yamagata Kamurodake clearly illustrate the occurrence of a lava extrusion event at ca. 1.6 Ma.

For lava domes of Stage III, two K-Ar dates have been reported. KH-4 of Minamiomoshiroyama LD is 1.63 ± 0.19 Ma and KH-1 of Koazumadake LD is 1.79 ± 0.20 Ma. Iwata et al. (2020) reported a date of 1.54 ± 0.15 Ma for a rock from Omoshiroyama which is situated north of Minamiomoshiroyama. Date of Minamiomoshiroyama (KH-4; 1.63 ± 0.19 Ma) and adjacent Omoshiroyama (OM-1; 1.54 ± 0.15 Ma) are almost identical.

As reported above, we can conclude that the volcanic activity of the Banji-iwa Volcanic Rocks started at ca. 2.0 Ma and continued to ca. 1.4 Ma.

Older dates (ca. 2.0 Ma) are obtained from the Stage I and II volcanic products, Daitodake VR and Yamagata Kamurodake VRM. Younger dates differ from ca. 1.6 Ma (Yamagata Kamurodake VRM and Senoharayama VR) to ca. 1.4 Ma (Stage I and II volcanic products and Daitodake VR), but there are indistinguishable degrees of uncertainty for the dates.

Our K-Ar dating results suggested demarcation of the Banji-iwa Volcanic Rocks, which include Omoshiroyama and exclude Gantoyama because the volcanic active period of the Banji-iwa Volcanic Rocks (ca. 2.0–1.4 Ma) differs from that of southerly volcano of Gantoyama (0.5–0.3 Ma; Iwata et al., 2020) and because the period is not different from that of the northerly volcano of Omoshiroyama (OM-1; 1.54 ± 0.15 Ma, Iwata et al., 2020). Discrepancy of dates indicates lack of a genetic relation between the Banji-iwa Volcanic Rocks and the Gantoyama, whereas the coincidence of dates implies a genetic relation between the Banji-iwa Volcanic Rocks and Omoshiroyama.

Summary

K-Ar dates of the Banji-iwa Volcanic Rocks were ca. 2.0 Ma–ca. 1.4 Ma, reflecting no major difference between their volcanic stages in the Banji-iwa Volcanic Rocks. Dates of Daitodake VR are ca. 2.0–1.4 Ma. Dates of Yamagata Kamurodake VRM are ca. 2.0–1.6 Ma.

The volcanic active period of the Banji-iwa Volcanic Rocks (2.0–1.4 Ma) differs from that of Gantoyama (0.5–0.3 Ma; Iwata et al., 2020), but it is not different from that of Omoshiroyama (OM-1, 1.54 ± 0.15 Ma; Iwata et al., 2020). Discrepancy and coincidence of dates respectively indicate that the Banji-iwa Volcanic Rocks have no genetic relation with Gantoyama and have some genetic relation with Omoshiroyama.

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