K-Ar ages of the Izu-Bonin Islands

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(Received May 10, 1970)

Abstract—Several volcanic rocks from O-shima, Kozu-shima and Hachijo-jima of the Izu Islands, from Chichi-jima and Haha-jima of the Bonin Islands and from Iwo-jima of the Iwo Islands were dated by K-Ar method. The rocks from the Izu Islands give the ages of less than 2–3 m.y., while the ages of the rocks from Chichi-jima and Haha-jima are about 30–40 m.y. The rock from Iwo-jima indicates a very young K-Ar age of about 0.03 m.y. These results confirm that there is a clear difference in age of volcanic activity between the Izu Islands and the Bonin Islands. This difference has also been suggested geologically.

INTRODUCTION

The Izu-Bonin Islands are accompanied by the Japan and the Bonin Trenches on their east side. The Bonin Islands and the Iwo Islands are considered to form a part of double island arcs; the former belongs to the outer arc and the latter to the inner arc, respectively (e.g. UYEDA and SUGIMURA, 1968) (Fig. 1). For understanding the origin of the ocean floor and island arcs, it is very important to reveal the ages of islands.

From geological observations, the Bonin Islands are considered to be older than the Izu Islands and the Iwo Islands. Volcanic activity along the present submarine ridge underneath the Izu Islands is supposed to date from early Neogene forming a part of so-called 'Green Tuff activity'.

The purpose of the present study is to answer the following questions.

1) Is there any systematic difference in age among the respective islands?
2) What is the relationship between the ages of these islands and those of seamounts in the Northwestern Pacific which are reported by OZIMA et al. (1970)? The relationship between these ages would give us some clue to the origin of island arcs and trenches.
3) How much is the difference in age between the older and the younger islands which lie approximately parallel to each other?
For these purposes, several volcanic rocks which were considered to be oldest geologically in each island were selected and dated by K-Ar method.

**Samples and Sampling Localities**

Samples from O-shima, Kozu-shima and Hachijo-jima of the Izu Islands, from Chichi-jima and Haha-jima of the Bonin Islands and from Iwo-jima of the Iwo Islands were dated by K-Ar method.

The samples from the Izu Islands are geologically oldest rocks in each island. Most of them are volcanic rocks in situ and a few are accidental blocks which are derived from the basement of the islands. Their sampling localities and petrographic descriptions are given in the appendix. General scope of the geology of the Izu-Bonin Islands is reported by Tsuya (1937).
K-Ar ages of the Izu-Bonin Islands

EXPERIMENTAL PROCEDURES

A few pieces of rock samples of 5–10 g are fused by an induction heater and the extracted Ar is purified with Ti sponge at about 900°C. Ar analyses were made by isotope dilution method with $^{38}$Ar tracer, using a 15 cm radius Reynolds-type mass spectrometer.

Potassium was analyzed by using a two channel flame photometer with 500 ppm Li internal standard and 1250 ppm Na buffer.

The analytical errors in ages range from about ±5% to ±15%.

More details of the experimental procedures of K-Ar method used in our laboratory are reported elsewhere (OZIMA et al., 1967; KANEOKA, 1969).

RESULTS AND DISCUSSION

Results of K-Ar age determinations of rocks from the Izu-Bonin Islands are shown in Tables 1 and 2. Because of low K contents and comparatively young ages, some of the K-Ar ages indicate only older limits.

O-shima

Since rocks from O-shima show rather low K contents and young ages, only older limits of age can be obtained for them. These ages are calculated assuming that 3% of total atmospheric argon derived in a procedure corresponds to the maximum amount of radiogenic argon to be expected for the sample, though this seems to be an overestimate.

The maximum age for the sample 56091919 of Okata Volcano, O-shima is about 0.4 m.y. This is younger than the geologically estimated age of Okata Volcano, Pliocene (KUNO, 1958). Microscopic observation shows that all minerals from the sample are fresh. Hence, it is difficult to suppose that significant Ar loss has occurred for this sample. So far as this sample is concerned, an age in Pleistocene is more likely than in Pliocene.

The sample 56093015D, an accidental block in a mudflow deposit of O-shima Volcano contains some amount of clay minerals. This sample is quartz diorite which is supposed to form a part of the basement of O-shima Volcano. The maximum K-Ar age also shows that the sample is younger than about 2.1 m.y. Although there is a possibility of some Ar loss from the sample because of slight alteration, the age would not be much older than that obtained by K-Ar method.

The sample NI60030903b of Fudeshima Volcano, O-shima is supposed geologically to be of Pliocene (KUNO, 1958). The result shows that the sample would be younger than about 2.4 m.y. Microscopic observation indicates that all minerals of this sample are fresh. Ar loss, therefore, may not be serious for this sample and we conclude that the age of Fudeshima sample is in late Pliocene or in early Pleistocene.
Table 1. K-Ar ages of volcanic rocks from the Izu Islands

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rock type</th>
<th>Sample weight (g)</th>
<th>($^{40}$Ar)$^+$ (mole/g)</th>
<th>($^{40}$Ar) air (%)</th>
<th>($^{40}$Ar) tot. (%)</th>
<th>($^{40}$K) (mole/g)</th>
<th>($^{40}$Ar)$^+$ (mole/g)</th>
<th>($^{40}$K) (mole/g)</th>
<th>Age (m.y.)</th>
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<tbody>
<tr>
<td><strong>IZU ISLANDS</strong></td>
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<td><strong>O-shima</strong></td>
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<tr>
<td>S6091919</td>
<td>Hypersthene-bearing augite andesite</td>
<td>13.406</td>
<td>&lt;$2.114 \times 10^{-13}$</td>
<td>~100</td>
<td>0.282</td>
<td>8.573 $\times 10^{-9}$</td>
<td>&lt;$2.466 \times 10^{-5}$</td>
<td>&lt;$0.42$</td>
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<tr>
<td>S6093015D</td>
<td>Pyroxene quartz diorite</td>
<td>16.526</td>
<td>&lt;$1.920 \times 10^{-12}$</td>
<td>~100</td>
<td>0.503±0.025</td>
<td>1.529 $\times 10^{-8}$</td>
<td>&lt;$1.256 \times 10^{-4}$</td>
<td>&lt;$2.14$</td>
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<tr>
<td>N600030903b</td>
<td>Non-porphyritic basalt</td>
<td>12.074</td>
<td>&lt;$1.141 \times 10^{-12}$</td>
<td>~100</td>
<td>0.266</td>
<td>8.086 $\times 10^{-9}$</td>
<td>&lt;$1.411 \times 10^{-4}$</td>
<td>&lt;$2.41$</td>
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<td><strong>Kozu-shima</strong></td>
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<tr>
<td>N600071803</td>
<td>Altered rhyolite</td>
<td>4.755</td>
<td>2.853 $\times 10^{-12}$</td>
<td>91.9</td>
<td>5.67±0.16</td>
<td>1.724 $\times 10^{-7}$</td>
<td>1.655 $\times 10^{-5}$</td>
<td>0.28</td>
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<tr>
<td>N600072107</td>
<td>Biotite rhyolite obsidian</td>
<td>6.708</td>
<td>&lt;$3.870 \times 10^{-13}$</td>
<td>99.7</td>
<td>3.00±0.02</td>
<td>9.120 $\times 10^{-8}$</td>
<td>&lt;$4.229 \times 10^{-6}$</td>
<td>&lt;$0.08$</td>
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<tr>
<td>N67091704</td>
<td>Ferrohyp.-ferropig-ferronag. andesite</td>
<td>14.921</td>
<td>&lt;$9.612 \times 10^{-14}$</td>
<td>~100</td>
<td>0.390</td>
<td>1.186 $\times 10^{-8}$</td>
<td>&lt;$8.105 \times 10^{-6}$</td>
<td>&lt;$0.14$</td>
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<tr>
<td>N659071806</td>
<td>Olivine-hypersthene-augite gabro</td>
<td>13.238</td>
<td>1.982 $\times 10^{-12}$</td>
<td>91.2</td>
<td>0.525±0.006</td>
<td>1.596 $\times 10^{-8}$</td>
<td>1.242 $\times 10^{-4}$</td>
<td>2.12</td>
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1) * radiogenic $^{40}$Ar.
2) ± means the reproducibility of the measurement.
3) $\lambda e = 0.585 \times 10^{-10}$ y$^{-1}$, $\lambda B = 4.72 \times 10^{-10}$ y$^{-1}$, $^{40}$K/$^{40}$Ar = 1.19 $\times 10^{-4}$ mole/mole.

Table 2. K-Ar ages of volcanic rocks from the Bonin and Iwo Islands

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rock type</th>
<th>Sample weight (g)</th>
<th>($^{40}$Ar)$^+$ (mole/g)</th>
<th>($^{40}$Ar) air (%)</th>
<th>($^{40}$Ar) tot. (%)</th>
<th>($^{40}$K) (mole/g)</th>
<th>($^{40}$Ar)$^+$ (mole/g)</th>
<th>($^{40}$K) (mole/g)</th>
<th>Age (m.y.)</th>
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<td><strong>BONIN ISLANDS</strong></td>
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<td><strong>Chichi-jima</strong></td>
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<tr>
<td>R382</td>
<td>Augite-hypersthene andesite</td>
<td>7.671</td>
<td>5.036 $\times 10^{-11}$</td>
<td>36.7</td>
<td>1.08±0.01</td>
<td>3.283 $\times 10^{-8}$</td>
<td>1.534 $\times 10^{-3}$</td>
<td>26.0</td>
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<td><strong>Haha-jima</strong></td>
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<tr>
<td>N69021002</td>
<td>Augite-orthopyroxene andesite</td>
<td>4.651</td>
<td>1.147 $\times 10^{-10}$</td>
<td>48.2</td>
<td>1.63±0.01</td>
<td>4.955 $\times 10^{-8}$</td>
<td>2.315 $\times 10^{-3}$</td>
<td>39.3</td>
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<td><strong>Iwo-jima</strong></td>
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<tr>
<td>N68082304</td>
<td>Augite-olivine trachyandesite</td>
<td>14.802</td>
<td>1.693 $\times 10^{-13}$</td>
<td>98.3</td>
<td>3.61±0.01</td>
<td>1.097 $\times 10^{-7}$</td>
<td>1.544 $\times 10^{-6}$</td>
<td>0.03</td>
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</table>
From these results it is supposed that the oldest rocks of O-shima which are now exposed above the sea level would be equal to or younger than 2–3 m.y. As the oldest rocks found in the Izu Peninsula is of lower Miocene (Kuno, 1950), O-shima seems to have been formed after the basement of the Izu Peninsula was formed.

Kozu-shima

K-Ar ages of rocks from Kozu-shima are rather young. The sample NI60071803 is from a lava flow of altered rhyolite and potassium feldspar of the rhyolite is considered to be secondary product replacing original plagioclase. Hence, the K-Ar age of 0.28 m.y. may not represent the age of the flow rock, but may be close to the age of the potassium feldspar formation.

The biotite rhyolite obsidian sample N160072107 is very fresh with the H₂O(+) content of 0.4% by weight and no significant Ar loss from the sample is supposed. Hence, it is concluded that the upper estimate of 0.08 m.y. by K-Ar method would be reasonable for the obsidian. This estimate is confirmed by the cross check between the K-Ar method and the fission track method: For the same obsidian, fission track age indicates 0.07 m.y. (KANEOKA and SUZUKI, 1970).

Because of the alteration of the rhyolite sample, only the younger limit of age is estimated to be about 0.3 m.y. for the rocks from Kozu-shima.

Hachijo-jima

The sample NI67091704 of andesite from Hachijo-jima is unconformably overlain by Higashi-yama Volcano whose age is supposed to be several ten thousand years from geological evidences. K-Ar age indicates that this sample is also young.

However, the sample NI55071806 of gabbro shows the K-Ar age of about 2.1 m.y. This sample is an accidental block in pumice tuff of Higashi-yama Volcano. The rock might be a part of the basement of Hachijo-jima. Microscopic observation shows that augite and hypersthene are altered to actinolite and iron ore, and olivine to serpentine. The age of this sample, therefore, may be older than the K-Ar age. So far as the volcanic rocks from Hachijo-jima are concerned, their age would be rather young.

Chichi-jima

The sample R382 of pyroxene andesite from Chichi-jima is slightly altered. Hence, the K-Ar age of 26 m.y. may be a little younger than the true age of the andesite. Geologically the rocks from Chichi-jima are supposed to be of upper Eocene or lower Oligocene. According to the time scale by HOLMES (1960), Oligocene ranges from 25 to 40 m.y. Considering the effect of alteration on K-Ar age, the sample would be about 30 m.y. or a little older and of Oligocene age.

Haha-jima

The sample NI69021002 of pyroxene andesite from Haha-jima also shows alteration of pyroxene. Hence, the K-Ar age of about 40 m.y. may be slightly younger than
the true age. For this sample, Ar analyses were made in duplicate and the result shows reasonable reproducibility. The K-Ar age is about 40m.y. Geologically, the rock of Haha-jima is supposed to be of Eocene. Consequently, the result of K-Ar age determinations is in good agreement with the geologically estimated age, considering that the K-Ar age generally indicates the minimum age of the sample.

**Iwo-jima**

The sample NI68082304 from Iwo-jima is a trachyandesite and its potassium content is high. Because of the extremely high air argon contamination, it is difficult to obtain a reliable K-Ar age. Only rough estimate can be made to give about 0.03 m.y.

From these results, it can be said that the K-Ar ages of the samples from the Bonin Islands and the Iwo Islands are generally in good accordance with geologically estimated ages.

**Summary**

1) Because of scantiness of age data, it is difficult to draw any definite conclusions as to the existence of systematic chronological sequence for the Izu-Bonin Islands. The time when the volcanic activity started in the Izu Islands cannot be determined definitely from the present result. So far as the rocks used in this study are concerned, however, they seem to be not so old as early Neogene, but late Tertiary or early Pleistocene. O-shima seems to be younger than the oldest exposed rocks of the Izu Peninsula which is believed to be of early Miocene.

2) From the result of K-Ar age determinations on dredged samples from the seamounts in the Northwestern Pacific, the seamounts are supposed to have ceased eruption 70–90 m.y. ago (OZIMA et al., 1970), whereas the volcanic activity of Chichi-jima and Haha-jima in the Bonin Islands occurred about 30–40 m.y. ago. The Izu Islands, emerged parts of a submarine ridge, seem to have been active in volcanism since late Tertiary or early Pleistocene.

3) The K-Ar ages of volcanic rocks from Chichi-jima and Haha-jima are about 30–40 m.y., and no volcanic activity is observed at present. The K-Ar age of a volcanic rock from Iwo-jima is almost recent. Hence, so far as the present samples are concerned, there is a clear age gap between them.

**Acknowledgments**

The authors are grateful to Dr. M. OZIMA, Geophysical Institute, University of Tokyo, who read the manuscript and gave some comments. They also thank Prof. M. SATO of Tokai University, Dr. K. SUMI and Mr. K. ONO of Geological Survey of Japan, who kindly offered them some of the samples used in this study.
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APPENDIX: PETROGRAPHY OF THE ROCKS

Note on symbols: +++ abundant, ++ common, + rare, * very rare.

IZU ISLANDS

O-shima

Hypersthene-bearing augite andesite (56091919)

A lava flow of Okata Volcano which is unconformably overlain by O-shima Volcano, collected by K. SUMI and K. ONO.

Phenocryst: Plagioclase +, augite +, iron ore +, hypersthene *

Groundmass: Fine-grained and pilotaxitic. Plagioclase +++, clinopyroxene +++, iron ore +++, tridymite ++.

All minerals are fresh.

Pyroxene quartz diorite (56093015D)

An accidental block in a mudflow deposit of O-shima Volcano, collected by K. SUMI and K. ONO.

Coarse-grained and inequigranular. Plagioclase +++, quartz +++, augite partly altered to clay mineral +++, micropegmatitic intergrowth of quartz and sodic plagioclase +++, iron ore +++, apatite +.

Secondary mineral: Clay mineral +++, actinolite +, limonite (?) +.

Non-porphyritic basalt (N160030903b)

A schlieren in a dike related to Fudeshima Volcano which is unconformably overlain by O-shima Volcano.

Phenocryst: None.

Groundmass: Coarse-grained and intergranular. Plagioclase +++, clinopyroxene +++, iron ore +++, cristobalite +.

All minerals are fresh.
Kozu-shima

**Altered rhyolite (NI60071803)**

An oldest lava flow exposed on the northern coast.
Phenocryst: Potassium feldspar and white mica pseudomorph after plagioclase (?) ++, altered iron ore +, quartz +.
Groundmass: Altered. Feldspar ++++, quartz +++, white mica +, pyrite +.

**Biotite rhyolite obsidian (NI60072107)**

A part of a lava flow exposed on the eastern coast.
Phenocryst: Plagioclase +, biotite +, quartz *.
Groundmass: Glass with microlites and crystallites +++.
All minerals are fresh.

Hachijo-jima

**Ferrohypersthene-ferropigeonite-ferroaugite andesite (NI67091704)**

A lava flow of Yokoma-ga-ura Volcano which is unconformably overlain by Higashi-yama Volcano.
Phenocryst: Plagioclase ++, ferroaugite +, ferropigeonite +, ferrohypersthene +, iron ore +.
Groundmass: Fine-grained and pilotaxitic. Plagioclase ++++, clinopyroxene +++, iron ore +++, tridymite +, anorthoclase +, quartz +, apatite +.

**Olivine-hypersthene-augite gabbro (NI55071806)**

An accidental block in pumice tuff of Higashi-yama Volcano. Coarse-grained and inequigranular. Plagioclase +++, augite partly altered to aggregate of actinolite and iron ore +++, hypersthene partly altered to aggregate of actinolite and iron ore +++, olivine completely altered to aggregate of serpentine and iron ore +, quartz *, apatite *.

BONIN ISLANDS

Chichi-jima

**Augite-hypersthene andesite (R382)**

Phenocryst: Plagioclase ++, hypersthene +, augite +, iron ore +.
Groundmass: Glassy. Glass +++, plagioclase ++, clinopyroxene +, iron ore +, tridymite +, anorthoclase +, quartz +, apatite +.
Secondary mineral: Zeolite and clay mineral in vesicles and along cracks +.

Haha-jima

**Augite-orthopyroxene andesite (NI69021002)**

A sample from Kita-ko, offered by M. SATO of Tokai University.
Phenocryst: Plagioclase (25.4 vol%), orthopyroxene completely altered to iron saponite (2.3 vol%), augite (1.7 vol%), iron ore (0.9 vol%), apatite (trace).
Groundmass (69.7 vol%): Microcrystalline texture: Plagioclase, pyroxene completely altered to iron saponite, alkali feldspar (?), iron ore, quartz (secondary mineral?), apatite.

IWO ISLANDS

Iwo-jima

**Augite-olivine trachyandesite (NI68082304)**

A lava flow exposed on the east coast of Moto-yama.
Phenocryst: Andesine (5.3 vol%), olivine (0.8 vol%), iron ore (0.4 vol%), augite (0.3 vol%), apatite (0.1 vol%).
Groundmass (93.1 vol%): Oligoclase, clinopyroxene, alkali feldspar, iron ore; carbonate and yellow unidentifiable mineral, both secondary.