Trace element abundances
in the Quaternary volcanic rocks
of the Norikura volcanic chain, central Honshu, Japan

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(Received March 20, 1987: Accepted September 22, 1987)

Abundances of 16 trace elements including rare earths are determined by the instrumental neutron activation analysis for the Quaternary volcanic rocks of central Honshu, Japan.

There is no systematic lateral variation along the Norikura volcanic chain except for the older part of Ontake volcano and Ueno volcano. The across-arc variation along the transverse through Yatsugatake-Norikura-Hakusan volcanoes does not reveal a regular increase in the incompatible element abundances away from the volcanic front. Based on the incompatible element abundances normalized to SiO₂ = 50%, volcanoes in central Honshu are grouped into three, that is, Myoko and Kurohime (MK & KH), Yatsugatake (YT) and Norikura volcanic chain and Hakusan (NVC & HK) in increasing order. This variation can be explained by the difference in degree of partial melting and of the local enrichment of K and Rb in Myoko and Kurohime volcanoes.

INTRODUCTION

Systematic lateral variation of chemical compositions of the volcanic rocks is one of the well-documented features of the island arc volcanism. Zonation of the major element contents within the northeastern Honshu arc has been summarized by many authors (e.g., Kuno, 1959, 1966; Sugimura, 1960; Aramaki and Ui, 1983). Regional variations of trace element abundances and isotope ratios in Hokkaido and northeastern Honshu have been studied by Katsui et al. (1978), Masuda and Aoki (1979), Fujitani and Masuda (1981), Yoshida and Aoki (1984), Nohda and Wasserburg (1981) and Notsu (1983). Onuma et al. (1983) studied Sr/Ca-Ba/Ca systematics and Notsu et al. (1983) reported Sr isotopic ratios in the Izu region. These results of trace element and isotope geochemistry generally show the systematic across-arc lateral variation similar to those of major element chemistry.

However, in the central part of Honshu, where the northeastern Honshu and Izu-Mariana arcs meet and the width of the volcanic belt becomes widest, the aerial patterns of the chemical zonation are much complicated and shows local anomalies (e.g., Aramaki and Ui, 1983), except for the K/Hf ratios (Tatsumi and Nakano, 1984). This reflects the underground complexity of the subducting plates and/or the mantle wedge beneath the arc junction. It is the main aim of this paper to present the first order pattern of the whole-rock trace element abundances of this area where such data are so far very meager.

In central Honshu, Quaternary volcanoes belonging to the Norikura volcanic chain (NVC) are aligned in single file roughly in the north-south direction (Fig. 1). The only exception is Shirouma-Oike volcano at the northern end which is offset about 20km eastwards. This volcanic chain runs parallel neither with the volcanic front of the northeastern Honshu arc nor with that of the Izu-Mariana arc. Nevertheless, the volcanoes form a clear linear group with
remarkable petrographical similarities. Another group of Quaternary volcanoes, the Hakusan group, is located to the west of the Norikura volcanic chain. They form a rather randomly arranged group displaced from the volcanic front up to 160km to the west.

**SAMPLES AND ANALYTICAL METHODS**

Samples were collected from eleven volcanoes (solid triangles in Fig. 1) and analyzed for the major and trace elements. These include all the members of the Norikura volcanic chain (NVC), Hakusan volcano (HK); a member of the Hakusan volcano group, Myoko (MK) and Kurohime (KH); members of the Myoko volcano group (Hayatsu, 1976) and Yatsugatake (Kawachi, 1961) volcano (YT). Two to ten samples were collected from each volcano. Descriptions of the analyzed samples are given in the appendix.

Abundances of 16 trace elements (La, Ce, Sm, Eu, Tb, Yb, Lu, Rb, Sr, Ba, Th, Hf, Ta, Sc, Cr and Co) are determined by the instrumental neutron activation analysis (INAA) using gamma-ray spectrometry with a Ge(Li)-detector and a multi-channel pulse-height analyzer, at the Department of Chemistry, Gakushuin University. Analytical procedure and experimental errors are essentially the same as those reported in Fujii et al. (1984). The analytical errors are, at the worst, less than 10% for most of the elements. Major element contents are obtained from the published reports, and where unavailable...
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SiO₂ and K₂O are given in wt% and others in ppm. --: not determined.

*From the literatures (see appendix).

**Analyzed by H. Haramura.
able, determined by the X-ray fluorescence analysis (XRF) at the Geological Institute, University of Tokyo. Details of the analytical method and errors are reported by Matsumoto and Urabe (1980). All the major element analyses cited from the reports are made on the same samples as those for the trace element analyses.

RESULTS AND DISCUSSION

Trace element abundances are listed in Table 1 together with SiO$_2$ and K$_2$O contents. Variation diagrams of some trace elements plotted against SiO$_2$ are shown in Figs. 2, 3 and 4. Chondrite-normalized REE (rare earth elements) patterns are shown in Figs. 5 and 6. The normalizing values are taken from the average chondrite of Ma et al. (1981).

Variation diagrams of the most of the elements plotted against SiO$_2$ show fairly well defined trend lines for individual volcanoes. With increasing SiO$_2$, Rb, Ba, Th, La, Hf and Ta increase, while Sr and Sc decrease (Figs. 2 to 4). These features are the same as those in northeastern Honshu as demonstrated by Masuda and Aoki (1979) and Yoshida and Aoki (1984).

Most volcanoes are composed of rocks belonging to the calc-alkaline rock series while Ontake, Myoko, Kurohime and Yatsugatake volcanoes are composed of both calc-alkaline and tholeiitic rock series. Sakuyama (1981) distinguished the N- and R-types in rocks of Myoko and Kurohime volcanoes. The N-type rocks (nearly equivalent to the tholeiitic rocks) are derived by the fractional crystallization of basaltic magma, while R-type ones (nearly equivalent to the calc-alkaline rocks) by the

![Fig. 2. K$_2$O and trace elements vs. SiO$_2$ variation diagrams of Myoko and Kurohime volcanoes. R-type rocks (solid symbols) exhibit indications of magma mixing, while N-type ones (open symbols) do not (Sakuyama, 1981). All values are given in ppm except for SiO$_2$ and K$_2$O (wt %).](image-url)
mixing of basalt and its differentiated magmas.

Variation diagrams of $K_2O$ and some trace elements plotted against $SiO_2$ for Myoko and Kurohime volcanic rocks are shown in Fig. 2. Though $SiO_2$ contents of R-type rocks are generally higher than those of N-type ones as pointed out by Sakuyama (1981), systematic differences of trace element abundances at a given $SiO_2$ do not exist between the two types. Though important from the petrological point, these subdivisions (tholeiitic or calc-alkaline) are not taken into account as they appear to show little difference in trends of trace element abundances in the area treated in this report.

Myoko volcano group (Myoko and Kurohime volcanoes) Myoko and Kurohime volcanoes are members of the Myoko volcano group (Hayatsu, 1976). Though they are only 8 km apart, they exhibit clear differences in chemical composition (Fig. 2). Rocks of Myoko volcano contain higher $K_2O$, Rb, Ba and Th (Fig. 2) and light REE (see La in Fig. 2) than those of Kurohime at a given $SiO_2$ content. Though both volcanoes are located more than 40 km farther from the volcanic front than Yatsugatake, they show more near-front characteristics, that is, generally lower concentrations of incompatible elements at a given $SiO_2$.

Variation within the Norikura volcanic chain

Rocks from the volcanoes belonging to the Norikura volcanic chain including Shirouma-Oike show no systematic variation in the $K_2O$ level, though Ba values scatter rather widely in the $SiO_2$ variation diagrams (Fig. 3). Most of the rocks in the volcanic chain show weak or no Eu anomalies and generally show REE patterns similar to one another (Fig. 5). Though Shirouma-Oike volcano is geographically shifted closer to the Myoko volcano group (Fig. 1), there is no significant difference in chemistry between Shirouma-Oike and the other volcanoes of the volcanic chain (Figs. 2 and 3). Though

![Fig. 3. Trace elements vs. SiO2 variation diagrams of the Norikura volcanic chain. All values are given in ppm except for SiO2 (wt %).](image-url)
the chain extends about 130km north-south oblique to the volcanic front, no systematic geographic variation can be recognized. The only exceptions are the older Ontake and Ueno volcanoes.

There is no prominent difference between the REE patterns of the older and younger Ontake rocks (Fig. 5d). As already pointed out by Kobayashi et al. (1975), rocks of the older part of Ontake are characterized by higher K2O content than those of the younger part of Ontake and other volcanoes of the same chain. Rb and Hf contents are also higher at a given SiO2 content (Fig. 3). The older and younger parts of Ontake are separated by a period of large-scale pyroclastic fall/flow eruptions which is related to the formation of a caldera. No such major geological hiatuses are found in other volcanoes of the same chain except Tateyama volcano where large-scale pyroclastic flow preceded the caldera formation. In the case of Tateyama, changes of chemical compositions between pre- and post-caldera ejecta cannot be examined, because no significant volcanic ejecta are detected prior to the pyroclastic eruption.

REE patterns of Ueno volcano are not radically different from those of other volcanoes of the Norikura volcanic chain regardless of Ueno's weak positive Eu anomalies (Fig. 5c). Rocks of Ueno volcano show distinctly lower K2O, Ba and Th and higher La, Hf and Ta contents (Fig. 3), however, the older age (1.41 ± 0.12 Ma; Uto and Yamada, 1985) relative to other volcanoes (late Pleistocene) may show that Ueno volcano belongs to a different volcanic province from other volcanoes discussed in this report.

Across-arc variations To test the across-arc variation in the concentration of K2O (Dickinson, 1975) and other components, the traverse Yatsugatake—Norikura—Hakusan volcanoes is chosen. The traverse makes an angle of 60—70 degrees with the volcanic front of Izu-Mariana

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Fig. 4. Trace elements vs. SiO2 variation diagrams of Yatsugatake and Hakusan volcanoes. Ranges of the Norikura volcanic chain are also shown. All values are given in ppm except for SiO2 (wt%).
Fig. 5. Chondrite-normalized REE patterns of volcanic rocks of the Norikura volcanic chain (NVC). No systematic changes are recognizable from north to south among the REE patterns of NVC volcanoes. a: Shirouma-Oike (SO) and Tateyama (TT). b: Washibadake-Kumonotaira (KW) and Yakedake (YK). c: Norikura (NR) and Ueno (UE). REE patterns of NR are shown as dotted area. d: Ontake (OT). Solid triangles older Ontake. REE patterns of younger Ontake are shown as dotted area.

arc and crosses the Norikura volcanic chain nearly at right angles (Fig. 1). Hakusan volcano is located furthest from the volcanic front (140 km; Aramaki and Ui, 1978) and Yatsugatake the nearest (20 km) among the volcanoes studied in this report. The K$_2$O values against SiO$_2$ do not regularly increase away from the front. They are lower in Hakusan rocks than in rocks of Norikura volcano. La, Rb, Sr, Ba, Th, Hf and Ta contents of Hakusan rocks at a given SiO$_2$ are similar to those of the Norikura volcanic chain (Fig. 4). Yatsugatake rocks are characterized by lower Th, La, Rb, Hf and Ta values at a given SiO$_2$ than rocks of Norikura volcanic chain and Hakusan volcano, as well as K$_2$O values. It is well established that light REE contents and light REE/heavy REE (LREE/HREE) ratio increase from the trench side to the back-arc side across the northeastern Honshu arc (Fujimaki and Kurasawa, 1980; Fujitani and Masuda, 1981). There is no appreciable difference in light REE contents and LREE/HREE ratios between the rocks of Norikura (La=23.2–33.7, La/Yb=9.5–17.7) and Hakusan (La=21.4–31.4, La/Yb=11.3–16.5 except one sample), while Yatsugatake rocks show distinctly low values (La=8.4–14.0, La/Yb=5.6–12.9) (Figs. 5 and 6). These results show the similarity of chemistry of Hakusan volcanic rocks to that of the Norikura volcanic chain. Thus the general picture points to the fact that rocks of Hakusan volcano are anomalously shifted toward the near-front chemistry for its location relative to the volcanic front, in regard to K$_2$O and other incompatible elements and REE chemistry.

Comparison of chemistry among the three volcanic groups in central Honshu In Fig. 7, the relationships between La and Th contents of the three volcanic groups, that is, Myoko and Kurohime (MK & KH), Yatsugatake (YT) and Norikura volcanic chain and Hakusan (NVC & HK), are shown. The three groups are distinguished also in this diagram.
Trace elements in the Quaternary volcanic rocks

Fig. 6. Chondrite-normalized REE patterns of volcanic rocks of Hakusan, Yatsugatake, Myoko and Kurohime volcanoes. a: Hakusan; Open circles with solid lines older Hakusan, solid circles with dotted lines younger Hakusan. b: Myoko; Open circles with solid lines N-type rocks, solid circles with dotted lines R-type rocks. c: Yatsugatake; Solid triangles with dotted lines older Yatsugatake, solid circles with dotted lines south Yatsugatake, open circles with solid lines younger Yatsugatake. d: Kurohime; Symbols are the same as in b.

Fig. 7. La-Th relations in Quaternary volcanic rocks of central Honshu. Symbols of Norikura volcanic chain and Hakusan are the same as in Figs. 4 and 5.

For comparison, the normalized values of incompatible elements to SiO$_2$=50% may be used (Table 2). They are generally lowest for Myoko and Kurohime and highest for Norikura volcanic chain and Hakusan.

We consider that the rocks with 50% SiO$_2$ have already undergone fractionation of plagioclase, olivine, augite and/or magnetite, judging from the phenocryst assemblages and bulk FeO*/MgO weight ratios (FeO* is total iron as FeO). K, Rb, Ba, La, Th and Hf all have small distribution coefficients for these minerals (D < 1), while Ta is less incompatible with magnetite (D=1.0; Gill, 1981). However, the effect of magnetite fractionation is thought to be less important than those of plagioclase, olivine and

<table>
<thead>
<tr>
<th></th>
<th>K$_2$O</th>
<th>Rb</th>
<th>Ba</th>
<th>La</th>
<th>Hf</th>
<th>Th</th>
<th>Ta</th>
</tr>
</thead>
<tbody>
<tr>
<td>MK &amp; KH</td>
<td>0.79</td>
<td>17</td>
<td>180</td>
<td>5.5</td>
<td>1.3</td>
<td>0.9</td>
<td>–</td>
</tr>
<tr>
<td>YT</td>
<td>0.83</td>
<td>18</td>
<td>270</td>
<td>9.5</td>
<td>2.2</td>
<td>1.5</td>
<td>0.16</td>
</tr>
<tr>
<td>NVC &amp; HK</td>
<td>1.10</td>
<td>26</td>
<td>350</td>
<td>16</td>
<td>3.5</td>
<td>2.7</td>
<td>0.36</td>
</tr>
</tbody>
</table>

All values are in ppm except for K$_2$O (wt %).
pyroxene, as Sakuyama and Nesbitt (1986) showed that magnetite makes up less than 10\% of total amounts of fractionated minerals from primary magmas to magmas with SiO2=50\% for rocks in northeastern Honshu.

Tatsumi et al. (1983) selected basalts with FeO*/MgO ratio less than 2 and estimated the chemical compositions of primary magmas, assuming the olivine maximum fractionation and judging whether the magma can be in equilibrium with the mantle olivine on the basis of the Fe-Mg exchange partitioning between olivine and liquid. It is assumed that magmas whose major element compositions are normalized to SiO2=50\%, are derived from their primary magmas only by olivine maximum fractionation. The normalized FeO*/MgO ratios are less than 2 (1.68 for Myoko and Kurohime, 1.92 for Yatsugatake and 1.92 for Norikura volcanic chain and Hakusan). Using the method of Tatsumi et al. (1983), we obtained the compositions of primary magmas and amounts of fractionated olivine crystals. The results are 19\% for Myoko and Kurohime, 21\% for Yatsugatake and 22\% for Norikura volcanic chain and Hakusan in terms of fraction of fractionated olivine. Trace element concentrations in primary magmas are calculated by Rayleigh fractional crystallization model (Allègre et al., 1977):

\[ C_1 = C_0 \cdot f^{(D_l-1)} \]  

where C\textsubscript{1} and C\textsubscript{0} are the concentrations of an element i, in the liquid and the initial liquid (primary magma), respectively. f is a liquid fraction (liquid/initial liquid) and D\textsubscript{i} is a distribution coefficient of an element i. The results are listed in Table 3.

Conversely, the amounts of fractionated minerals can be obtained using the mixing calculation of Bryan et al. (1969), if compositions of primary magmas are known. If we take the primary high alumina basalt magma determined by Tatsumi et al. (1983) as the primary magma, the mixing calculation gives: 16\% olivine and 5\% augite for Myoko and Kurohime, 16\% olivine, 9\% augite, 1\% orthopyroxene and 8\% plagioclase for Yatsugatake and 13\% olivine, 10\% augite, 7\% orthopyroxene, 13\% plagioclase and 1% magnetite for Norikura volcanic chain and Hakusan. These results strongly suggest that olivine, augite and plagioclase fractionation are the most important.

Using the equation (1), effects of fractionation of plagioclase and augite may be examined. If the total amount of fractionated olivine increases from 15\% to 30\% (twofold), the calculated primary compositions of these incompatible elements decreases only by 18\%. La has the largest distribution coefficient for plagioclase (D=0.2) and Ta for augite (D=0.3) (Gill, 1981). A 20\% fractionation of plagioclase instead of olivine increases the estimated La value of primary magma by only 4\%. Also, a 20\% fractionation of augite instead of olivine increases the Ta value of primary magma by only 7\%. Thus, no serious difference may be caused by fractionation of either plagioclase or augite. The values given in Table 3 may not be largely affected.

These estimated values are not inconsistent with those of northeastern Honshu obtained by Sakuyama and Nesbitt (1986). They are plotted in Fig. 8 as normalized to the values of primordial mantle proposed by Wood et al. (1979). This figure shows the strong depletion of HFS elements (Hf and Ta) relative to LIL elements (K, Rb, Ba etc.), that is the typical chemical characteristics of island-arc magmas (e.g., Perfit et al., 1980). These three patterns are nearly parallel with each other, which suggests that these primary magmas are generated from similar sources, which are also similar to that of northeastern Honshu.

Unless source mantle is initially heterogeneous in regard to trace element abundances,
Trace elements in the Quaternary volcanic rocks

Fig. 8. Trace element concentrations in primary magmas normalized to those in the primordial mantle proposed by Wood et al. (1979). Those in northeast Honshu estimated by Sakuyama and Nesbitt (1986) are shown as dotted area.

The variation of primary magma compositions would be caused by the effect of degree of partial melting and/or that of addition of slab-derived fluid phase. Calculations of the degree of partial melting are made except for K and Rb of Myoko and Kurohime on the basis of bulk distribution coefficients determined by Sakuyama and Nesbitt (1986), using the equation of Shaw (1970):

\[
\frac{C_1}{C_0} = \frac{1}{D_i + F(1-D_i)}
\]

where \(C_1\) and \(C_0\) are the concentrations of an element \(i\), in the partial melted liquid and the original solid, respectively. \(F\) is a weight fraction of the liquid, that is, degree of partial melting, and \(D_i\) is a bulk distribution coefficient of an element \(i\).

It is assumed that trace element concentrations, \(C_0\) in equation (2), in the source mantle are kept constant beneath the central Honshu.

If we assume \(F\) is 0.1 for Yatsugatake, the \(F\) for Myoko and Kurohime and Norikura volcanic chain and Hakusan may be calculated as 0.15–0.20 and 0.04–0.07, respectively. Based on the averaged degree of partial melting calculated above, K and Rb concentrations in the primary magma of Myoko and Kurohime should be 0.39% and 8.3 ppm, respectively, which are much lower than the values shown in Table 3. This suggests that K and Rb have been added to the source mantle of Myoko and Kurohime volcanic rocks.

Sr isotope ratios \(^{87}\text{Sr}/^{86}\text{Sr}\) in basaltic rocks available from the previous works are 0.70378–0.70436 for Myoko and Kurohime (Ishizaka et al., 1977), 0.70372–0.70388 for Yatsugatake (Matsuhisa and Kurasawa, 1983) and 0.70569 for Ontake volcano (Matsuhisa and Kurasawa, 1983). The fact that the Sr isotope ratio for Myoko and Kurohime is not at all anomalously high might indicate that K and Rb contents in their primary magma are due to the higher concentrations of K and Rb in the original mantle rather than they are due to the addition of slab-derived fluid rich in these elements.

CONCLUSIONS

1. No systematic lateral variation of \(K_2O\), Rb, Ba, Th, Hf and Ta contents and REE pattern is found in the Quaternary volcanic rocks of the Norikura volcanic chain with the exceptions of the rocks of older Ontake volcano and Ueno volcano with higher and lower \(K_2O\), respectively.
2. There are significant differences in chemical compositions between Shirouma-Oike volcano (belonging to the Norikura volcanic chain) and the Myoko volcano group, although they are located close to each other.
3. Rocks of Hakusan volcano resembles in chemistry those of the Norikura volcanic chain except that the former are slightly lower in \(K_2O\).
4. Abundances of some incompatible elements (K, REE, Rb, Th etc.) do not show a simple enrichment from the trench side to the back-arc side in central Honshu (Yatsugatake – Norikura...
Hakusan), where northeastern Honshu and Izu-Mariana arcs meet and the volcanic belt becomes widest.

5. Incompatible element values (K, Rb, Ba, La, Th, Hf and Ta) normalized to SiO$_2$=50% are lowest in Myoko and Kurohime, and highest in Norikura volcanic chain and Hakusan in central Honshu. These variations are explained by the differences of degree of partial melting except for K and Rb, which may reflect the mantle heterogeneity.

Acknowledgements—We would like to express our appreciation to Profs. M. Yamasaki, S. Kawachi and the late Dr. M. Sakuyama who offered rock samples. We also thank Dr. Y. Tatsumi for his encouragements. The manuscript was greatly improved by the critical reading by Prof. K. Notsu.

References


Nagaoka, M. (1972) Geology and petrological study of
Trace elements in the Quaternary volcanic rocks


APPENDIX

Sample description

Myoko (MK-denoted Nos.) and Kurohime (KH-denoted Nos.)

Samples were offered by late Dr. M. Sakuyama. Sakuyama (1981) described the detailed petrography, reporting major chemical compositions of these samples analysed in this study.

Yatsugatake (YT-denoted Nos.)

YT-342: Hyp-Ol-Aug andesite, Chausuyama lava
YT-381: Ol-Hyp-Aug andesite, Minami-Yokodake upper lava (South Yatsugatake)
YT-1110: Hb dacite, Inakodake lava
YT-3200: Hyp-Aug-Hb dacite, Futagomine lava
YT-3234: Aug-Ol basalt, Kasuga volcanic rocks (older Yatsugatake)
YT-3566: Hb-Aug-Ol andesite, Yokodake basal lava
YT-3823: Hyp-Aug andesite, Minenomatsumi lava

Yatsugatake volcano in this paper includes both North and South Yatsugatake. Samples were offered by Dr. S. Kawachi. Above geological units correspond to those of Kawachi (1974, 1977). Major chemical compositions of YT-1110 are obtained from Kawachi (1974) and those of others are from Aramaki (unpublished).

Hakusan (HK-denoted Nos.)

HK-13: Bi-Qz-bearing Hyp-Hb andesite, older Hakusan
HK-33: Ol-bearing Hyp-Hb andesite, older Hakusan
HK-42: Qz-bearing Hyp-Hb andesite, older Hakusan
HK-109: Qz-bearing Hyp-Hb andesite, younger Hakusan
HK-114: Qz-bearing Hyp-Hb andesite, younger Hakusan
HK-119: Ol-bearing Hb-Hyp andesite, younger Hakusan

Samples were offered by Prof. M. Yamasaki (collected by Dr. M. Nagaoka). HK-42 was dated as 0.11 Ma by the K-Ar method (as OH-1 in Higashino et al., 1984). HK-13 and HK-109 are blocks in pyroclastic flow deposits, while others are lava flow samples. The older and younger Hakusan correspond to Nagaoka (1972) and Nagaoka et al. (1985). All samples analyzed contain augite microphenocrysts (Nagaoka, 1972).

Shirouma-Oike (SO-denoted Nos.)

Samples were offered by late Dr. M. Sakuyama. Major chemical compositions are available from Sakuyama (1979).

Tateyama (TT-denoted Nos.)

TT-12: Hb-Aug-Hyp dacite, Tamadono lava
TT-15: Bi-Hyp-Hb andesite, Tenguyama lava

Washibadake-Kumonotaira (KW-denoted Nos.)

KW-05: Ol-Hyp-Aug-Hb andesite, lava of Washibadake
KW-15: Hb-Hyp-Aug andesite, lava of Kumonotaira

Yakedake (YK-denoted Nos.)

YK-05a: Hyp-Aug-Bi-Hb andesite, lava of Yakedake lava dome
YK-08: Qz-Aug-Hyp-Bi-Hb dacite, welded tuff of Warudaniyama

Norikura (N-denoted Nos.)

N-010c: Aug-Hyp andesite, Bandokoro lava
N-088: Qz-Bi-Ol-Hb-bearing Hyp-Aug andesite, Marihiten lava
N-102a: Aug-bearing Hyp dacite, Kengamine lava
N-107: Bi-Hb-bearing Aug-Hyp andesite, Murodo lava
N-112: Hb-bearing Aug-Hyp andesite, Sencho lava
N-118a: Qz-Bi-Aug-bearing Hyp-Hb andesite, Daikoku lava
N-137: Aug-Hb-Hyp andesite, Byobudake agglutinate
N-153: Bi-Ol-Qz-bearing Hb-Aug-Hyp andesite, Yotsudake lava
N-157: Qz-Bi-Ol-bearing Aug-Hyp-Hb andesite, Ebisu lava
N-167: Qz-Bi-bearing Hb-Aug-Hyp andesite, Eboshi lava

Ontake (OT-denoted Nos.)

OT-1: Aug-Hyp andesite, III, (SA79103102)
OT-4: Ol-Hyp-Aug andesite, III
OT-9: Hb andesite, I
OT-19: Aug-Ol basaltic andesite, III
OT-24: Hb-Hyp-Aug andesite, I
OT-30: Ol basalt, I
OT-31: Hyp-Aug andesite, IV
OT-36: Aug-Hyp andesite, I
OT-40: Aug-Hyp-Hb andesite, I

Numbers (I-IV) correspond to the effusion stages of Kobayashi et al. (1975). The stage I is the older Ontake and the stage II-IV are the younger Ontake. OT-1 sample is an essential block in a pyroclastic flow deposit, while others are lava samples.

Ueno (UE-denoted Nos.)

UE-1: Aug-bearing Ol basaltic andesite
UE-2: Ol basaltic andesite

Both samples were collected from Ueno volcano of Sameshima (1955). The sampling point of UE-1 is the same as that of Uto and Yamada (1985)'s 74031305 which was dated as 1.41±0.12 Ma.