

Petrology of the Higashi-Izu Monogenetic Volcano Group

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Abstract

The Higashi-Izu monogenetic volcano group is situated in the north-eastern part of the Izu Peninsula and is composed of more than 70 monogenetic volcanoes scattered in the area 350 km² wide.

Tephrochronological studies indicate that the volcanism of the Higashi-Izu monogenetic volcano group started 30,000 years ago and continued up until less than 3,000 years before present. Actually the activity possibly began much earlier than 30,000 years ago.

The SiO₂ contents of the rocks from this volcano group show a bimodal distribution: i.e., one group in the range from 49 to 60 wt.% (basalts-andesites) and the other in the range from 68 to 74 wt.% (dacites). Phenocryst assemblages of the basalt-andesite group are olivine±plagioclase, olivine+plagioclase+clinopyroxene, and olivine+plagioclase+clinopyroxene+orthopyroxene. Andesites contain granitic xenocrysts (quartz, plagioclase, hornblende and opaques). The phenocryst assemblage of dacite is plagioclase+orthopyroxene+hornblende+magnetite+ilmenite. Dacite dome lavas contain basaltic xenocrysts (magnesian olivine, Ca-rich plagioclase and clinopyroxene). The rocks of the olivine+plagioclase assemblage are mostly confined to the northern part of the area and those of the olivine+plagioclase+clinopyroxene assemblage to the southern part of the area. The rocks of the olivine+plagioclase+clinopyroxene+orthopyroxene assemblage are concentrated in the eastern part of the latter.

The rocks containing xenocrysts are mostly confined to the north-eastern part of the area.

Most of the rocks without xenocrysts of this volcano group fall within the high-alumina basalt series field and those with phenocrysts fall in the tholeiitic rock series field in the SiO₂ versus total alkali diagram.

The anhydrous melting experiments of basalts suggest that the unknown but limited amount of water enough to affect the phase relations was dissolved in the basaltic magmas before eruption.

Most of the andesite magmas of the Higashi-Izu monogenetic volcano group were produced by the contamination of the basaltic magma with the granitic rocks constituting the crust under the Izu Peninsula. This is supported by the positive correlation between the amount of xeno-

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crysts and the SiO_2 and Al_2O_3 contents and by rare-earth element data. The rocks showing evidence of such contamination are distributed mostly in the northeastern part of the region.

Groundmass pyroxene assemblage changes from augite+pigeonite or augite+pigeonite+hypersthene in basalts to augite+pigeonite+hypersthene or augite+hypersthene in andesites. This change is related to the degree of contamination, the hypersthene-bearing assemblages being the product of a more advanced stage of contamination.

Dacite magma was probably produced by the partial melting of the granitic rock constituting the crust by the heat of the basaltic magma. This is supported by the close occurrence of the basic and acidic magmas in time and place, the existence of basaltic xenocrysts in dacites and the existence of the granitic xenoliths and xenocrysts in basic magmas. Also this is suggested by the major element and rare-earth element data.

1. Introduction

The rocks constituting the Izu Peninsula are mostly the products of the volcanic activities. The basement of this Peninsula is composed of submarine volcanic products of the Miocene age (the Yagashima Group and the Shirahama Group). The Yagashima Group consists of the basaltic, andesitic, rhyolitic lavas and pyroclastic rocks,

though basic materials are prominent. The rocks of this Group suffered various degrees of alteration. The Shirahama Group consists mainly of intermediate to acidic pyroclastic rocks, with a lesser amount of basaltic rocks, sandstone and limestone. White tuff is characteristic of this Group.

Many subaerial volcanoes were built on the Peninsula during the Quaternary age; Taga volcano, Ida volcano, Daruma volcano, Tanaba volcano, Usami volcano, Amagi volcano, Jaishi volcano, Nanzaki volcano and Higashi-Izu monogenetic volcano group (Fig.

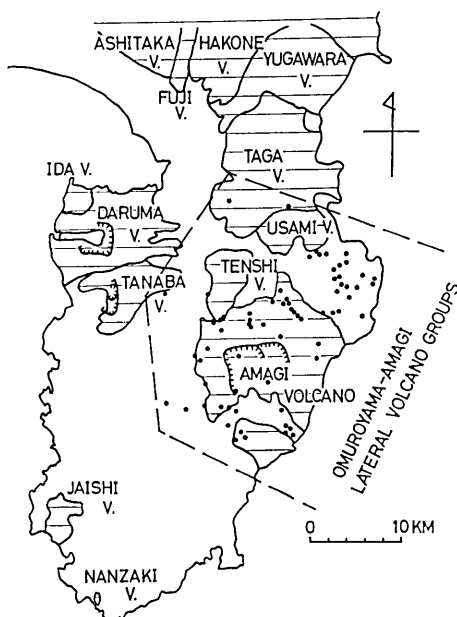


Fig. 1. Index map of the Higashi-Izu monogenetic volcano group. Dots indicate the locations of eruption centers.

Table 1. List of names, kinds of ejecta and volcanic edifice, and rock name of vents of the Higashi-Izu monogenetic volcano group.

Name of unit	Kinds of ejecta and volcanic edifice	Rock name	Name of unit	Kinds of ejecta and volcanic edifice	Rock name
33 Takatsukayama	C, P	B	40 Jizōdō 2	P	B
34 Sukumoyama	C, P	B	41 " 3	?	B
1 Hachigakubo 1	P	B	42 " 4	C, P	B
2 " 2	P	B	43 Kawagodaira	M, P, PF	D
3 " 3	P	B	44 Shiranutanoike	M	?
4 " 4	C, P	B	45 Amagi Highland- higashi	P	B
31 " 5	C, P	B	46 Sekiguchi 1	C, P	B
5 Uchino	C, P	B	47 " 2	C, P	B
6 Joboshi	C, P	B	48 " 3	C, P	B
10 Akasaka-minami	C, P	?	49 Yugaoka	P	B
11 Kadono	C, P	B, A	50 Inatori 1	C, P	B
12 Ikeda-higashi	C, P	?	51 " 2	C, P	B
29 Arayama	C, P	B	52 " 3	C, P	B
13 Ogi	C, P	?	53 " 4	C, P	?
14 Ippeki-ko	M	?	54 Ōike	P	B
15 Higashi Ōike	M	?	55 Koike	P	B
7 Komuroyama	C, P	A	56 Ōikeminami	P	B
16,17 Chikubo	C, P	A	57 Hachiyama	C, P	B
8 Kawana-minami	C, P	B	58 Kannonyama-higashi	C, P	B
9 Sannohara-kita	C, P	B	59 Hachiyama- higashioku	C, P	B
18 Takamuroyama	C, P	B	60 Ōdaira	P	B
32 Harai	?	A	61 Noborio-minami	P	B
19 Ōmuroyama	C, P	A	62 Numanokawa 1	P	B
20 Dainoyama	D	A	63 " 2	C, P	B
21 Iyuzan	C, P	A	64 " 3	?	B
30 Akakubo	C, P	A	65 Hacchō-rindō	P	B
22 Yahazuyama	D	D	66 Hontanigawa-shiryu	P	B
23 Ananoyama	D	D	67 Maruyama	C, P	B
24 Ananokubo	?	B	68 Hachikuboyama	C, P	B
28 Fujimikubo	M	?	69 Yoichizaka	P	B
25 Iwanokubo-higashi	C, P	B	70 Nagano	C, P	B
26 Iwanokubo-nishi	C, P	B	71 Hōkibara-higashi	M	?
27 Iwanoyama	D, P	A~D	72 Nagano-higashi	C, P	B
35 Ōhatano	M	?	73 Kitanohara-higashi	M	?
36 Marunoyama	C, P	B	74 Funabara	C, P	B
37 Togasayama	S	B	75 Sekiguchigawa-jōryu	P	B
38 Sugehiki	P	B			
39 Jizōdō 1	P	B			

P: pyroclastic fall deposit, PF: pyroclastic flow deposit, C: pyroclastic cone and tuff ring, M: maar-like circular depression without pyroclastic cone, D: lava dome, S: small stratovolcano, A: andesite, B: basalt, D: dacite.

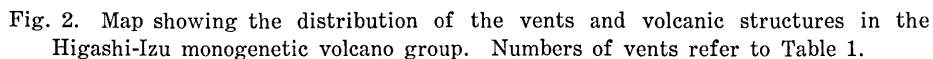
1). Large volcanoes in the Izu Peninsula ceased their activities during the Pleistocene age.

The most recent volcanism occurred in the northern part of the Izu Peninsula a few tens of thousand years ago after those volcanoes had finished their activities. The volcanoes distributed in the north-eastern part of the activity region (Fig. 1) were called the Omuroyama volcano group" (TSUYA, 1930; KUNO, 1954). Those distributed in the Amagi region were called the Amagi lateral volcano group "(KURASAWA, 1959). As no difference exists between these two volcano groups in age, mode of activity and character of magma, these volcano groups are newly named "the Higashi-Izu monogenetic volcano group" (ARAMAKI and HAMURO, 1977).

This volcano group is composed of more than 70 small monogenetic volcanoes produced individually by one eruptive cycle scattered in an area of 350 km² (Table 1). However, other volcanoes, except the Nanzaki volcano, in the Izu Peninsula are large polygenetic ones produced by repeated eruptive cycles, typically observed in island arcs. The Higashi-Izu monogenetic volcano group is also characterized by bimodal volcanism. A relatively large volume of basaltic magma and a small volume of dacitic magma, while other Quaternary strato-volcanoes are characterized by unimodal volcanism mostly composed of andesitic magma.

KUNO (1954) pointed out the existence of the hypersthenic rock series and the pigeonitic rock series through detailed petrographical observations and chemical analyses in these rocks. He also pointed out that the rocks of the hypersthenic rock series always contain xenocrysts probably derived from granitic rocks and those of the pigeonitic rock series were free of xenocrysts. KUNO (1966) proposed that the aphyric basalts of central Honshu and the Izu Islands, Japan, may be classified into three types; tholeiite, high-alumina basalt and alkali basalt. The rocks from the Omuroyama volcano group and Amagi volcano group were classified as high-alumina basalt. KURASAWA (1959) surveyed the distribution of the lava flows and gave the chemical analyses of major and minor elements on the rocks from the Amagi volcano group. He also pointed out that the basaltic rocks from the Amagi volcano group had a similar character to those of the Omuroyama volcano group.

A monogenetic volcano is produced by an activity which lasted for a single eruptive cycle, which is defined as a series of eruptive events (NAKAMURA *et al.*, 1963). Generally the activities of a single eruptive cycle occur in the following order: 1) the eruption of pyroclastic materials, 2) the extrusion of pyroclastic flows, and 3) the extrusion



of lava flows. However, the mode of occurrence is somewhat different depending on the character of the magmas. In the case of the basic magma, the activity begins with the eruption of pyroclastic materials, mostly scoria and ash. The erupted scoria and ash deposit in a concentric circle and its thickness decreases rapidly from the eruption center, as seen at Omuroyama (HAMURO, 1978). Also a pyroclastic cone is built in this stage around the eruption center such as the Omuroyama, Hachiyama and Hachikuboyama cones (Nos. 19, 57 and 68 in Fig. 2 and Table 1 respectively). The extrusion of pyroclastic flow is rare for basaltic magmas. No pyroclastic flow deposit of basic com-

position is identified in this volcano group.

When the intensity of eruption of pyroclastic materials decreases the extrusion of lava flows begins. In many cases lava flows extrude from the foot of pyroclastic cones. Usually after that the activity ends. However, there are some repeat pyroclastic eruptions and extrusions of lava flows. Some of them end with only an eruption of pyroclastic materials. In the case of acidic magmas the magnitude of activities is diverse. In the Higashi-Izu monogenetic volcano group, the activity of the Kawagodaira crater (No. 43 in Fig. 2 and Table 1) is the greatest. Pyroclastic materials of dacitic composition that erupted from this crater are widely distributed in the Izu Peninsula (SAMEJIMA, 1969). After the extrusion of pyroclastic flows from this crater, a thick lava flow extruded. The formation of dacite lava dome is another type of activity. This type shows a rather small magnitude of activity in the Higashi-Izu monogenetic volcano group. After it small quantity of pyroclastic materials erupted, the dacite magma extruded and formed a lava dome such as at Yahazuyama and Iwanoyama (Nos. 2, 23 and 27 respectively in Fig. 2 and Table 1).

The sequence of activity of the Higashi-Izu monogenetic volcano group is summarized in Fig. 3 (ARAMAKI and HAMURO, 1977, HAMURO, 1978a, 1978b). The C^{14} ages indicate that the activity of this volcano group started at least 30,000 years ago and continued till about 3,000 years ago or later. Judging from the available stratigraphic data the activity probably began more than 30,000 years ago. Dacite volcanism joined with the basic volcanism only since 3,000 years ago.

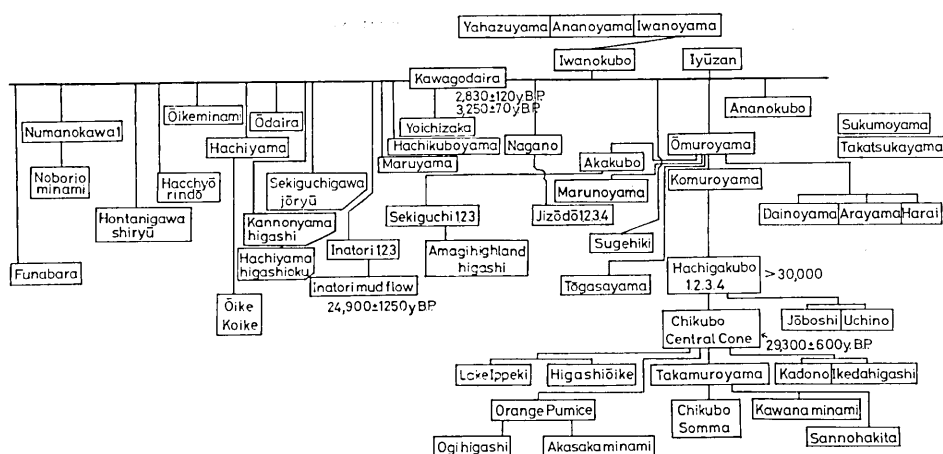


Fig. 3. Block diagram showing the stratigraphic relation of the vents of the Higashi-Izu monogenetic volcano group. Lines connecting the squares indicate that the age relation between the connected vents is confirmed by tephrostratigraphy.

Table 2. Mineral assemblages of the rocks of the Higashi-Izu monogenetic volcano group. Ol:olivine, Pl:plagioclase, Cpx:clinopyroxene, Cpx A:augite, Cpx P:pigeonite, Opx:orthopyroxene, Hb:hornblende, Qz:quartz, Opxs:opaques, Gl:glass, Xeno:xenocrysts.

No.	Name of unit	Phenocryst			Mode of Phenocrysts (%)	Groundmass				Xeno (%)
		Ol	Pl	Cpx Opx Hb Qz Opxs		Ol	Pl	A	P Opx Opxs Gl	
33	Takatsukayama	*	*		4.8	*	*	*	*	*
34	Sukumoyama	*	*		3.3	*	*	*	*	*
1-4, 31	Hachigakubo	*	*		n.d.					*
5	Uchino	*	*		1.0	*	*	*	*	*
6	Jōboshi	*	*		3.7	*	*	*	*	*
74	Funabara	*	*		3.7	*	*	*	*	*
39	Jizōdō 1	*	*		14.2	*	*	*	*	*
40	Jizōdō 2	*	*		6.7	*	*	*	*	*
41	Jizōdō 3	*	*		n.d.	*	*	*	*	*
70	Nagano	*	*		n.d.	*	*	*	*	*
36	Maruyama	*	*		8.5	*	*	*	*	*
69	Yoichizaka	*	*		30.2	*	*	*	*	*
68	Hachikuboyama	*	*		12.1	*	*	*	*	*
66	Hontanigawashiryū	*	*		10.6	*	*	*	*	*
67	Maruyama	*	*		n.d.	*	*	*	*	*
65	Hacchyo-rindō	*	*		12.6	*	*	*	*	*
61	Noborio-minami	*	*		n.d.	*	*	*	*	*
62	Numanokawa 1	*	*		20.6	*	*	*	*	*
63	Numanokawa 2	*	*		6.6	*	*	*	*	*
64	Numanokawa 3	*	*		15.1	*	*	*	*	*
60	Odaira	*	*		3.6	*	*	*	*	*
59	Hachiyamahigashioka	*	*		14.4	*	*	*	*	*
57	Hachiyama	*	*		18.8	*	*	*	*	*
56	Ōike-minami	*	*		24.3	*	*	*	*	*
50	Inatori 1	*	*		6.9	*	*	*	*	*
51	Inatori 2	*	*		4.8	*	*	*	*	*

Table 2

No. Name of unit		Phenocryst				Mode of Phenocrysts (%)		Groundmass Cpx					Xeno (%)			
		Ol	Pl	Cpx	Opx	Hb	Qz	Opqs	Ol	Pl	A	P	Opx	Opqs	Gl	
46	Sekiguchi 1			*	*	*		sp	*	*	*	*	*	*	*	
75	Sekiguchigawajōryū			*	*	*		sp		*	*	*	*	*	*	
45	Amagi Highland-higashi			*	*	*		sp		*	*	*	*	*	*	
30	Akakubo			*	*	*	*	sp		*	*	*	*	*	*	*
21	Iyuzan			*	*	*		sp		*	*	*	*	*	*	7.4
24	Ananokubo			*	*	*		sp		*	*	*	*	*	*	*
25	Iwanokubo			*	*	*		sp		*	*	*	*	*	*	*
26				*	*	*		sp		*	*	*	*	*	*	*
7	Komuroyama			*	*	*		sp		*	*	*	*	*	*	6.5-16.8
8	Kawana-minami			*	*	*		sp		*	*	*	*	*	*	3.2
9	Sannohara-kita			*	*	*		sp		*	*	*	*	*	*	*
18	Omuroyama			*	*	*		sp		*	*	*	*	*	*	3.2- 8.8
32	Harai			*	*	*		sp		*	*	*	*	*	*	1.0
16	Chikubo			*	*	*		sp		*	*	*	*	*	*	8.0
17				*	*	*		sp		*	*	*	*	*	*	*
11	Kadono (L)			*	*	*		sp		*	*	*	*	*	*	*
	(U)			*	*	*		sp		*	*	*	*	*	*	*
38	Sugehiki			*	*	*		sp		*	*	*	*	*	*	*
37	Tōgasayama			*	*	*		sp		*	*	*	*	*	*	*
20	Dainoyama			*	*	*		sp		*	*	*	*	*	*	*
43	Kawagodaira			*	*	*		sp		*	*	*	*	*	*	*
27	Iwanoyama			*	*	*	*	M, I		*	*	*	*	*	*	*
23	Ananoyama			*	*	*	*	M, I		*	*	*	*	*	*	*
22	Yahazuyama			*	*	*	*	M, I		*	*	*	*	*	*	*

The purpose of this study is to clarify the petrological characters of the Higashi-Izu monogenetic volcano group with special emphasis on the following features: 1) petrographical and mineralogical characters of the rocks, 2) chemical characters of the rocks, 3) regional variation of petrography and chemistry of the rocks.

II. Petrography and mineralogy

The rocks of the Higashi-Izu monogenetic volcano group are divided into 3 groups of basalt (I, II and III), 3 groups of andesite (I, II and III) and 2 groups of dacite (I and II) based on the petrographical characteristics. Descriptions of each group are given below. Mineralogical assemblages of the rocks are listed in Table 2.

Basalt I

The rocks of Takatsukayama (No. 33 in Fig. 2 and Table 1), Sukumoyama (No. 34), Uchino (No. 5), Joboshi (No. 6), Jizodo 1, 2, 3 (Nos.

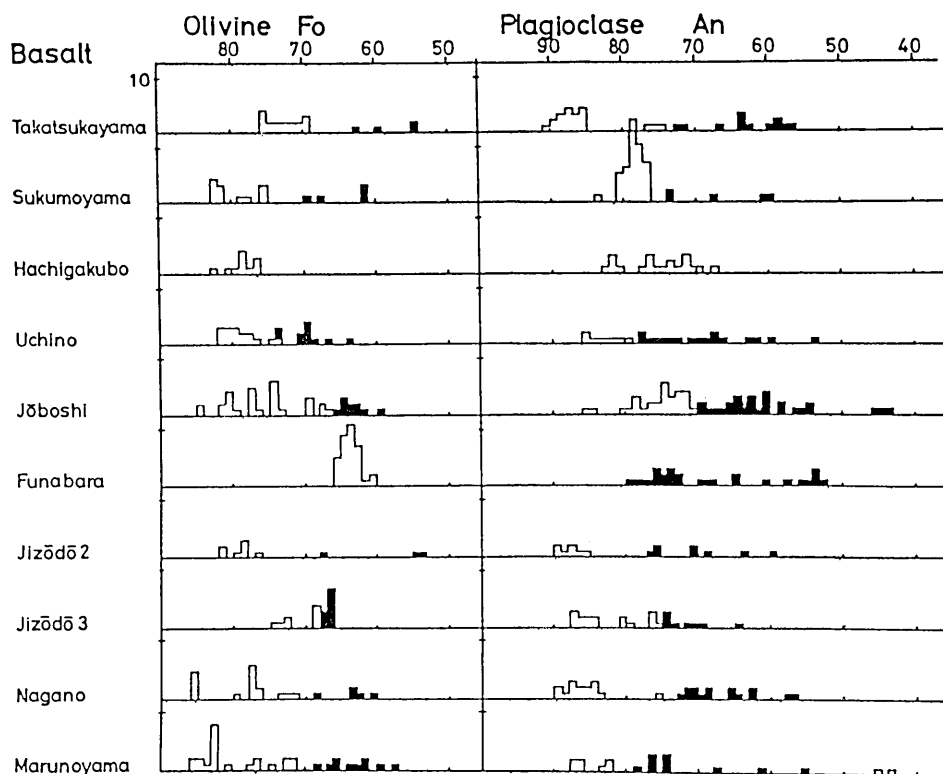


Fig. 4-1. Microprobe analyses of olivine and plagioclase (Fo and An mole %). □: phenocryst, ■: groundmass.

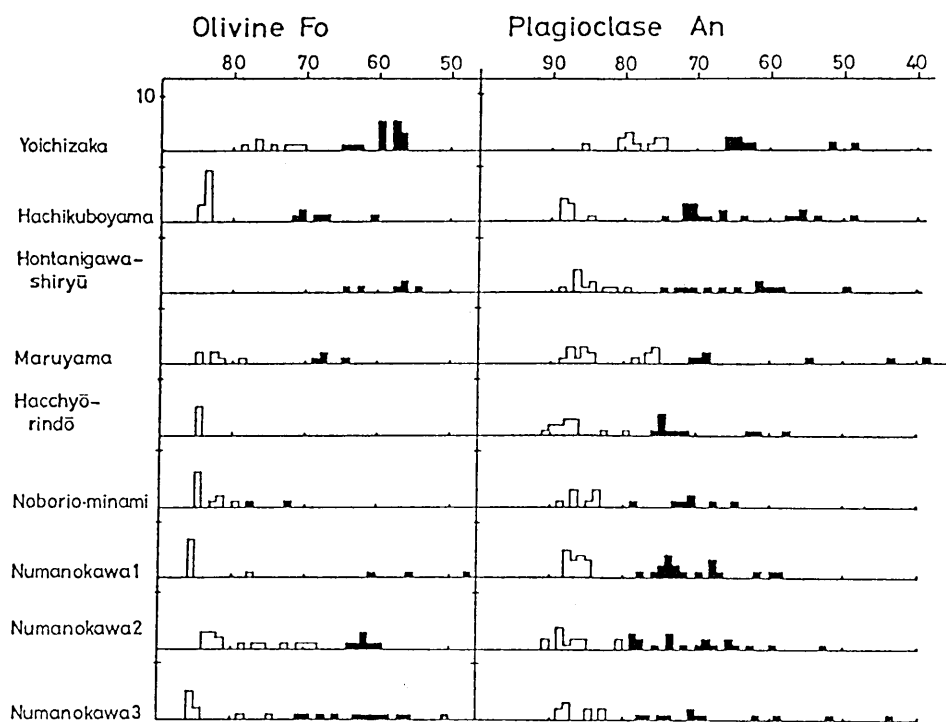


Fig. 4-2. Same as Fig. 4-1.

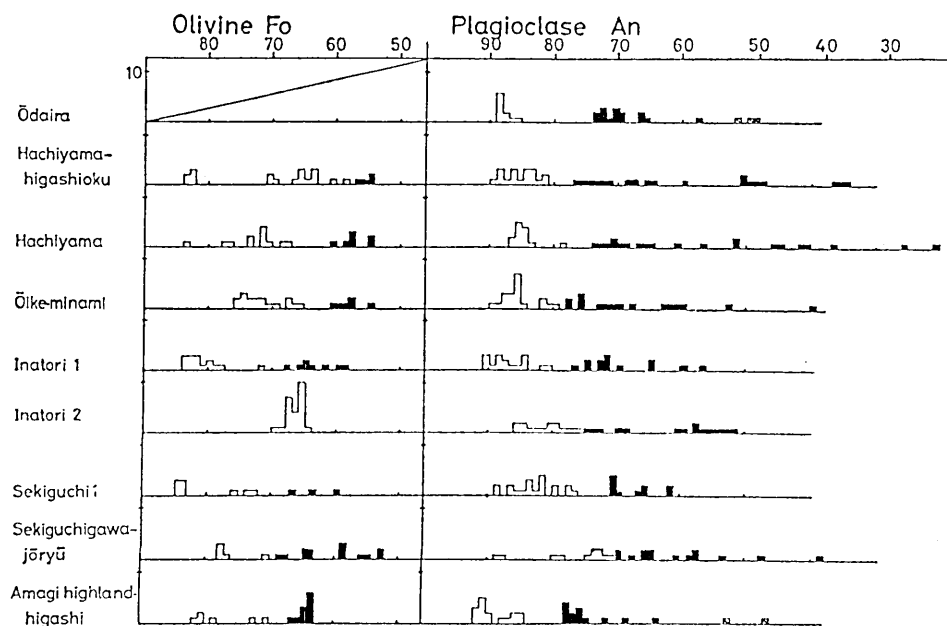


Fig. 4-3. Same as Fig. 4-1.

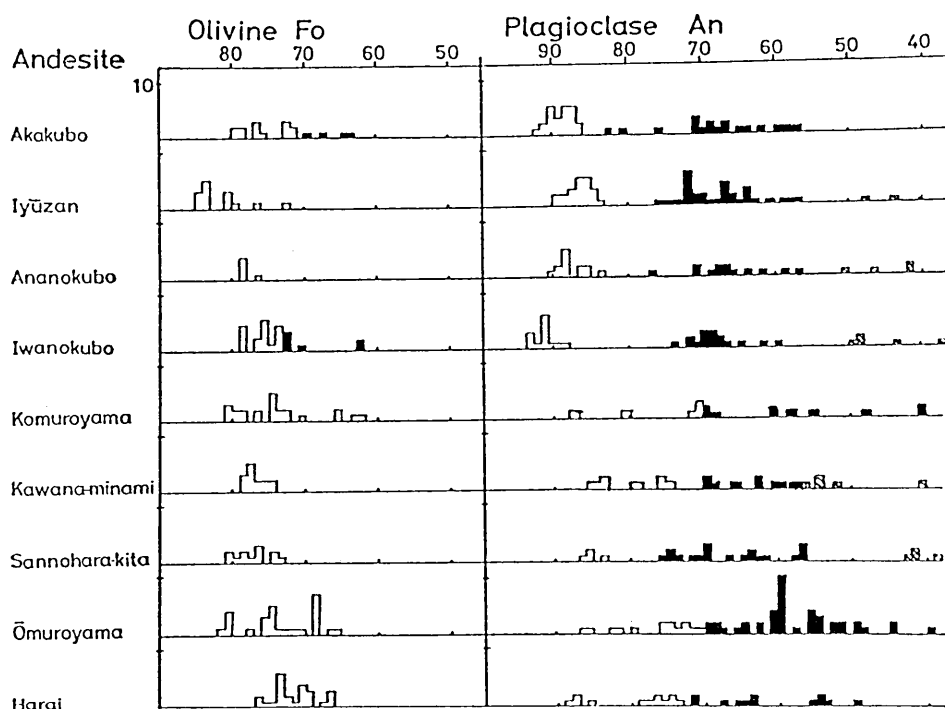


Fig. 4-4. Same as Fig. 4-1.

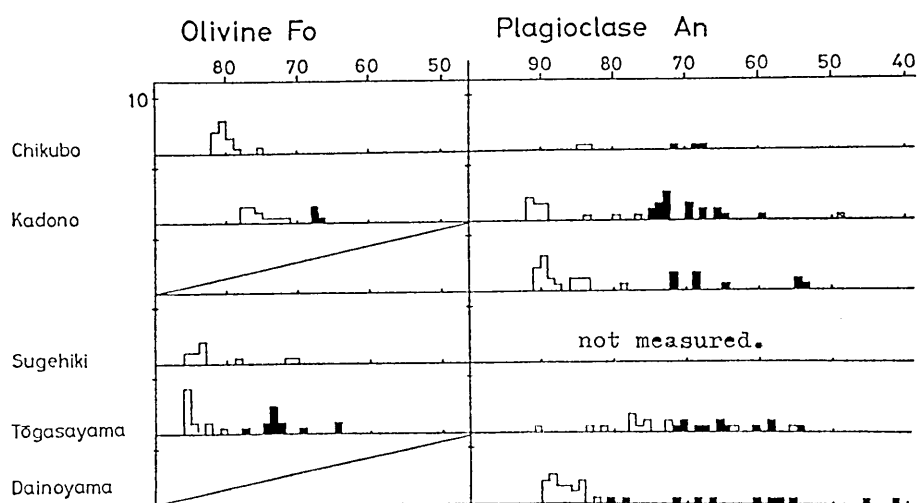


Fig. 4-5. Same as Fig. 4-1.

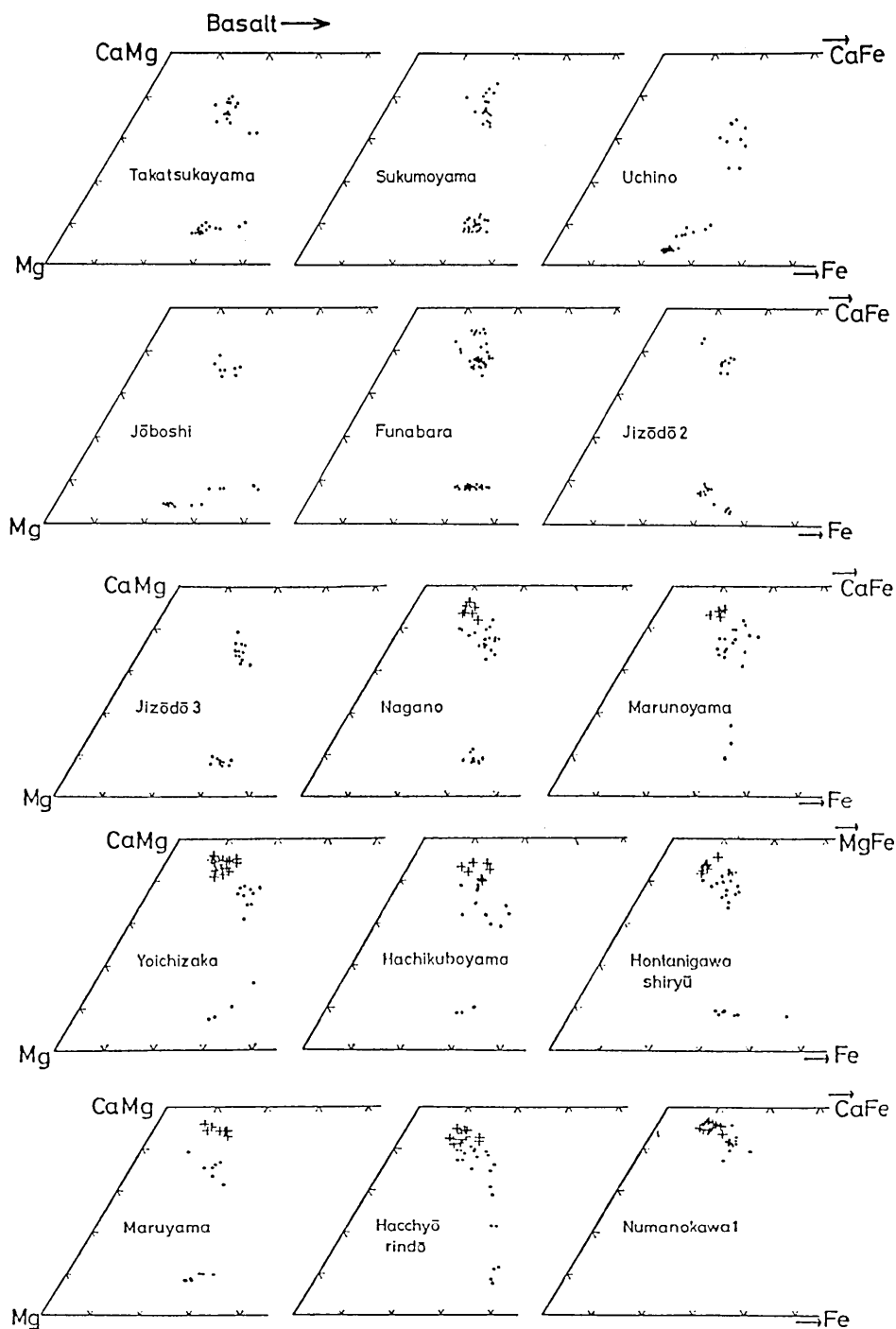


Fig. 5-1. Microprobe determinations of pyroxene quadrilateral (Atom %). + phenocryst, ● groundmass.

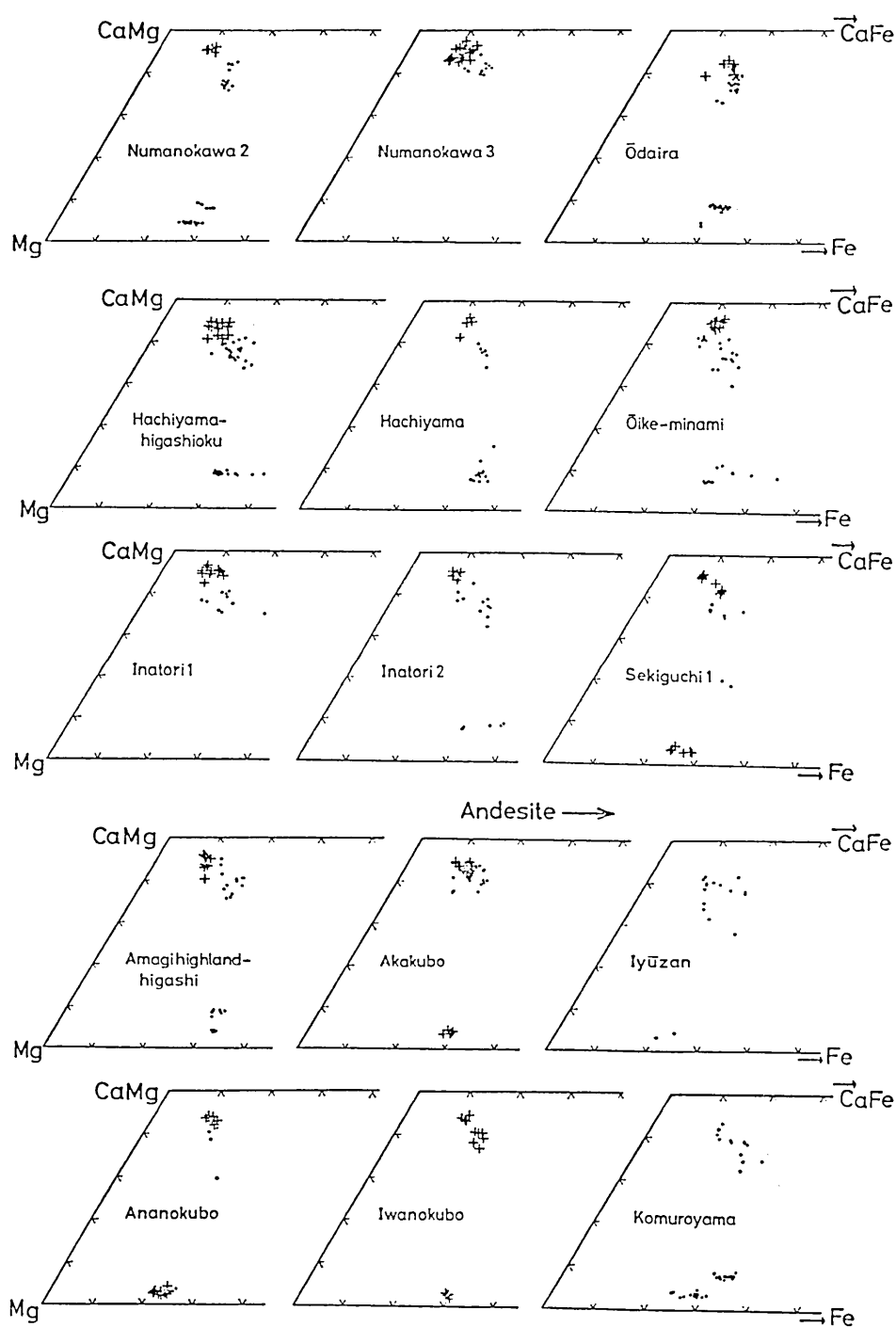


Fig. 5-2. Same as Fig. 5-1.

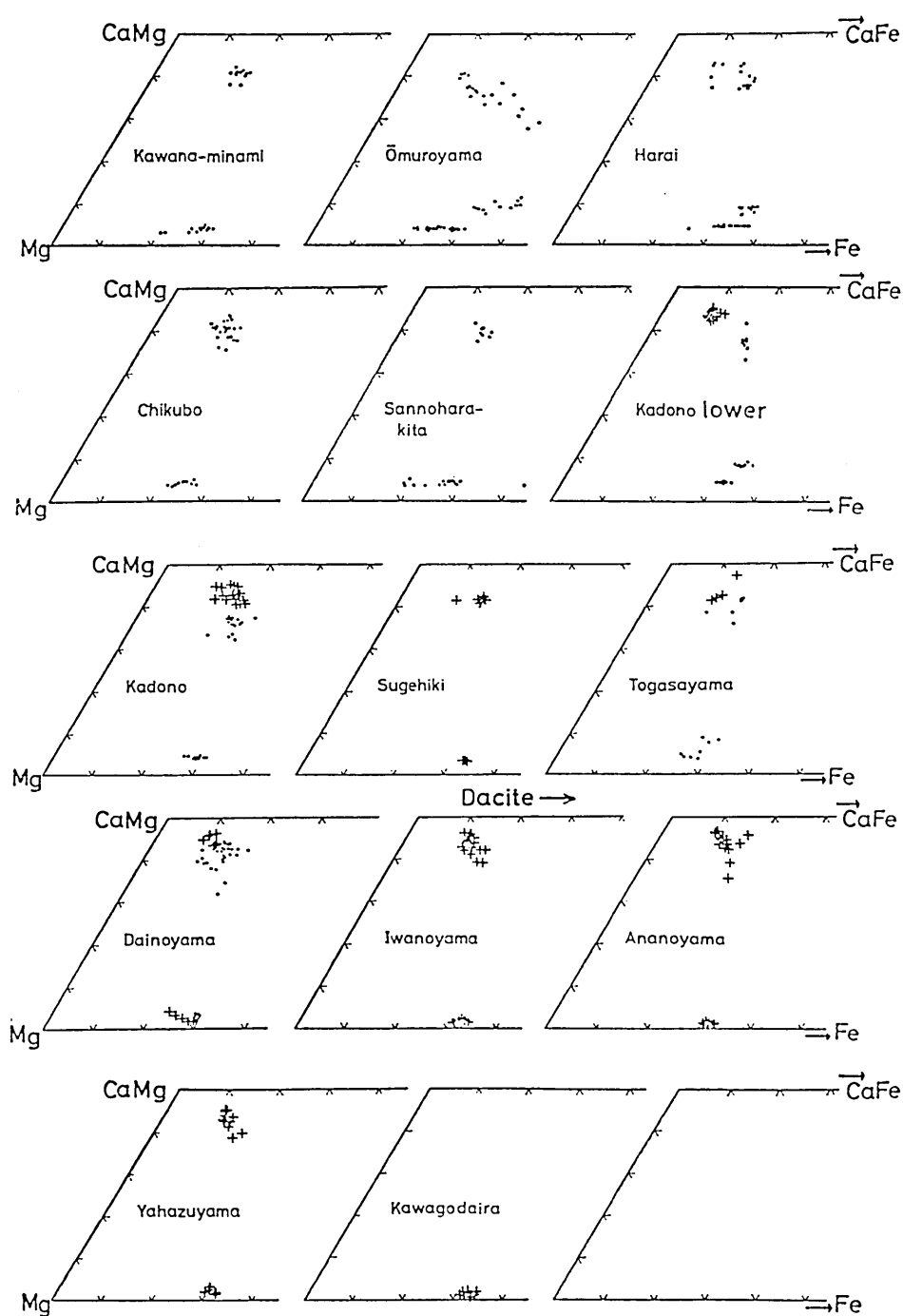


Fig. 5-3. Same as Fig. 5-1.

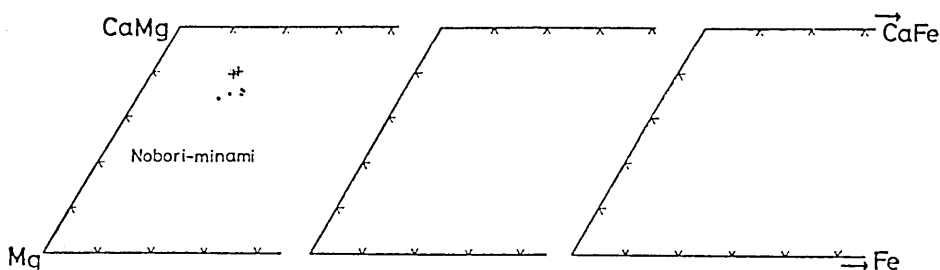


Fig. 5-4. Same as Fig. 5-1.

39, 40, 41 respectively), Funabara (No. 74) and scoria of Hachigakubo (Nos. 1, 2, 3, 4, 31) are grouped under Basalt I. These rocks are characterized by the presence of olivine and/or plagioclase phenocrysts.

Euhedral to subhedral olivine phenocrysts are always present in the rocks. Olivine phenocrysts show normal compositional zoning, i.e., the core is more forsterite-rich than the rim. Sporadic tiny grains of opaque or brown picotite are always included in the olivine phenocrysts. Plagioclase phenocrysts shows a euhedral outline with a relatively broad core high in anorthite content and a narrow rim high in albite, i.e. it exhibits the normal compositional zoning.

There are two groundmass assemblages in the Basalt I group. One is composed of olivine, plagioclase, augite, pigeonite and ore (Takatsukayama, Sukumoyama, Funabara, Jizodo 3), while the other is composed of olivine, plagioclase, augite, hypersthene, pigeonite and ore (Uchino, Joboshi, Jizodo 2). Sometimes a small amount of glass is present in both assemblages. The Scoria of Hachigakubo has a glassy groundmass. Some specimens of Funabara rarely contain microphenocrysts of augite.

The composition of olivine and plagioclase is presented in Fig. 4. The composition of pyroxenes is plotted in Fig. 5. Chemical analyses of minerals in the rocks of Joboshi and Sukumoyama are presented in Table 3.

Basalt II

The rocks of Yoichizaka (No. 69 in Fig. 2 and Table 1), Marunoyama (No. 36), Nagano (No. 70), Hachikuboyama (No. 68), Maruyama (No. 67), Hontanigawa-shiryu (No. 66), Haccho-rindo (No. 65), Noborio-minami (No. 61), Numanokawa 1, 2, 3 (Nos. 62, 63, 64 respectively), Hachiyama-higashioku (No. 58), Hachiyama (No. 57), Odaira (No. 60),

Table 3. Chemical composition of the minerals in the rocks of the Higashi-Izu mono-genetic volcano group. *: total Fe as FeO, P: phenocrysts, G: groundmass.

No.	OL-1 P	OL-2 P	OL-3 P	OL-4 P	OL-5 P	OL-6 P	OL-7 P	OL-8 P
SiO ₂	39.09	38.13	37.93	36.71	37.11	37.92	35.00	39.40
TiO ₂	.02	.02	.03	.03	.03	.01	.01	.00
Al ₂ O ₃	.00	.00	.00	.00	.00	.02	.03	.04
FeO*	18.26	25.94	26.84	28.96	16.82	21.01	33.93	15.62
MnO	.29	.47	.46	.42	.30	.34	.56	.21
MgO	42.06	35.88	35.14	33.24	44.37	41.02	29.99	45.25
CaO	.17	.27	.30	.21	.18	.18	.22	.22
Na ₂ O	.01	.00	.00	.09	.00	.00	.00	.00
K ₂ O	.00	.00	.00	.02	.00	.00	.00	.00
Total	99.90	100.71	100.70	99.72	98.81	100.50	99.74	101.08
Fo%	80.4	71.2	70.0	67.2	82.5	77.7	61.2	83.5

No.	OL-9 P	OL-10 P	OL-11 P	OL-12 P	OL-13 P	OL-14 P	OL-15 P	OL-16 P
SiO ₂	39.58	36.61	36.64	36.97	38.65	37.49	37.41	35.68
TiO ₂	.00	.00	.01	.03	.01	.00	.00	.00
Al ₂ O ₃	.05	.06	.09	.10	.02	.03	.04	.05
FeO*	15.62	21.92	29.78	28.32	18.71	22.32	20.35	36.53
MnO	.15	.32	.00	.00	.24	.37	.32	.35
MgO	45.35	39.74	32.43	33.70	41.83	38.92	41.59	26.27
CaO	.24	.24	.17	.13	.15	.20	.16	.16
Na ₂ O	.00	.00	.02	.04	.00	.00	.00	.00
K ₂ O	.00	.00	.00	.00	.00	.00	.00	.00
Total	100.99	100.89	99.14	99.29	99.61	99.33	96.87	99.04
Fo%	83.8	76.4	66.0	68.0	79.9	75.7	78.3	56.0

No.	OL-17 P	OL-18 P	OL-19 P	OL-20 P
SiO ₂	36.26	37.55	37.51	38.27
TiO ₂	.00	.03	.03	.02
Al ₂ O ₃	.03	.04	.03	.03
FeO*	22.21	20.66	20.99	21.30
MnO	.04	.38	.40	.38
MgO	40.64	40.40	40.85	39.99
CaO	.17	.14	.13	.15
Na ₂ O	.00	.09	.04	.02
K ₂ O	.00	.02	.02	.02
Total	99.71	99.31	100.00	100.18
Fo%	76.4	77.7	77.6	77

OL-1~4: Joboshi (KH-16, No. 9 in Table 4)

5~7: Sukumoyama (KH-13, No. 3)

8~10: Numamokawa 1 (KH-29, No. 22)

11~12: Kadono upper (KH-17, No. 53)

13~14: Omuroyama (KH-18, No. 46)

15~17: Komuroyama (KH-19, No. 42)

18~20: Ananokubo (KH-34, No. 37)

(Continued)

Table 3

No.	PL-1 P	PL-2 P	PL-3 P	PL-4 P	PL-5 P	PL-6 P	PL-7 P	PL-8 P
SiO ₂	46.72	47.87	48.27	49.10	50.08	47.06	47.37	46.85
TiO ₂	.03	.05	.04	.04	.05	.07	.05	.05
Al ₂ O ₃	33.83	32.41	32.46	31.83	31.40	33.00	32.52	33.85
FeO*	.63	.67	.66	.70	.81	.49	.48	.43
MnO	.00	.00	.00	.00	.00	.07	.09	.07
MgO	.10	.13	.16	.20	.14	.13	.13	.16
CaO	17.73	16.11	16.07	15.91	15.06	16.39	16.73	16.18
Na ₂ O	1.65	2.31	2.40	2.75	3.42	2.17	2.08	2.17
K ₂ O	.03	.06	.05	.06	.10	.04	.04	.04
Total	100.72	99.61	100.11	100.59	101.06	99.42	99.49	99.80
An%	85.5	79.1	78.5	75.8	70.3	80.5	81.4	80.3

No.	PL-9 P	PL-10 P	PL-11 G	PL-12 P	PL-13 P	PL-14 G	PL-15 G	PL-16 G
SiO ₂	45.30	50.41	48.71	45.26	48.91	50.65	52.03	50.61
TiO ₂	.02	.03	.02	.00	.06	.07	.03	.01
Al ₂ O ₃	35.14	32.00	31.57	34.85	31.18	30.11	27.84	30.47
FeO*	.60	1.27	.88	.67	.72	.85	.81	.61
MnO	.00	.00	.00	.00	.00	.00	.00	.00
MgO	.08	.11	.12	.09	.10	.17	.13	.08
CaO	18.47	12.03	15.90	19.04	15.24	13.80	13.97	14.97
Na ₂ O	1.18	3.26	3.16	.95	2.78	3.45	3.59	3.41
K ₂ O	.02	.18	.15	.02	.08	.12	.14	.16
Total	100.81	99.29	100.51	100.88	99.07	99.22	98.54	100.27
An%	89.5	66.3	72.9	91.6	74.8	68.3	67.7	70.2

No.	PL-17 P	PL-18 P	PL-19 P	PL-20 X	PL-21 P	PL-22 P	PL-23 X	PL-24 X
SiO ₂	45.75	45.88	46.18	55.43	55.79	55.86	45.01	45.69
TiO ₂	.01	.03	.04	.05	.05	.03	.00	.01
Al ₂ O ₃	34.33	33.52	33.91	27.10	27.28	27.10	34.00	33.51
FeO*	.50	.42	.54	.17	.26	.34	.47	.58
MnO	.05	.09	.10	.08	.00	.04	.01	.01
MgO	.09	.10	.09	.00	.03	.02	.05	.07
CaO	17.80	18.22	17.04	9.96	10.19	10.41	19.36	18.08
Na ₂ O	1.32	1.24	1.59	5.64	5.52	5.59	.84	1.24
K ₂ O	.04	.03	.07	.34	.17	.18	.00	.02
Total	99.89	99.53	99.56	98.77	99.29	99.57	99.74	99.21
An%	88	88.9	85.2	48.4	50.0	50.2	92.7	88.8

No.	PL-25 X	PL-26 P
SiO ₂	44.68	58.13
TiO ₂	.00	.00
Al ₂ O ₃	34.84	25.86
FeO*	.61	.20
MnO	.00	.04
MgO	.06	.03
CaO	18.71	8.54
Na ₂ O	.87	6.14
K ₂ O	.01	.25
Total	99.78	99.19
An%	92.2	42.8

PL- 1~ 5: Joboshi (KH-16, No. 9 in Table 4)
6~ 8: Numanokawa 1 (KH-29, No. 22)
9~12: Kadono upper (KH-17, No. 53)
13~14: Omuroyama (KH-18, No. 46)
15~16: Komuroyama (KH-19, No. 42)
17~20: Ananokubo (KH-34, No. 37)
21~25: Iwanoyama (KH-11, No. 60)
26: Kawagodaira (KH-36, No. 58)

(Continued)

Table 3

No.	Aug-1 G	Aug-2 G	Aug-3 G	Aug-4 P	Aug-5 P	Aug-6 P	Aug-7 P	Aug-8 P
SiO ₂	48.70	50.67	51.13	52.67	50.98	49.93	49.40	48.44
TiO ₂	.86	.52	.58	.50	.75	.79	.72	1.06
Al ₂ O ₃	5.91	2.71	2.23	3.11	4.24	5.72	4.95	5.41
FeO*	6.31	8.38	9.29	6.50	7.94	6.64	7.62	10.46
MnO	.19	.29	.28	.14	.15	.14	.00	.00
MgO	16.68	17.56	16.38	16.74	15.05	15.09	15.03	14.31
CaO	21.01	19.12	18.09	21.03	20.98	21.35	21.09	19.38
Na ₂ O	.22	.21	.30	.27	.37	.37	.25	.23
K ₂ O	.02	.02	.00	.00	.00	.00	.00	.00
Total	99.90	99.48	98.28	100.96	100.46	100.03	99.06	99.29
Wo	42.8	38.2	37.6	42.6	43.6	44.9	43.9	40.8
En	47.2	48.8	47.3	47.1	43.5	44.2	43.6	41.9
Fs	10.0	13.0	15.1	10.3	12.9	10.9	12.5	17.3

No.	Aug-9 P	Aug-10 P	Aug-11 P	Aug-12 P	Aug-13 G	Aug-14 G	Aug-15 G	Aug-16 G
SiO ₂	52.02	48.55	47.32	52.18	51.95	49.56	51.33	52.31
TiO ₂	.36	1.06	1.51	.41	.48	1.04	.57	.35
Al ₂ O ₃	2.61	5.74	7.25	2.50	2.63	3.53	1.87	1.30
FeO*	6.09	10.41	8.95	7.42	11.69	12.52	10.03	10.34
MnO	.00	.00	.00	.00	.00	.33	.31	.40
MgO	16.37	14.03	13.13	15.95	16.71	13.86	15.94	15.11
CaO	21.76	19.67	21.04	20.94	16.46	18.70	18.98	20.12
Na ₂ O	.25	.28	.28	.21	.20	.51	.27	.23
K ₂ O	.00	.00	.01	.00	.01	.01	.01	.00
Total	99.46	99.74	99.49	99.61	100.13	100.06	99.31	100.16
Wo	44.1	41.6	45.8	42.8	33.7	39.1	38.7	40.9
En	46.2	41.2	39.0	45.4	47.6	40.4	45.3	42.7
Fs	9.7	17.2	15.2	11.8	18.7	20.5	16.0	16.4

No.	Aug-17 G	Aug-18 G	Aug-19 G	Aug-20 P	Aug-21 P	Aug-22 G	Aug-23 X
SiO ₂	52.53	51.97	49.25	51.64	51.13	51.82	50.02
TiO ₂	.24	.58	.93	.39	.47	.46	.75
Al ₂ O ₃	.86	2.63	5.83	2.38	2.30	1.94	3.86
FeO*	10.62	8.67	8.34	6.63	7.00	8.88	8.53
MnO	.48	.24	.21	.23	.24	.33	.20
MgO	15.58	15.72	15.30	17.12	17.01	17.21	15.04
CaO	19.58	20.82	20.37	21.42	20.99	18.83	21.52
Na ₂ O	.28	.25	.23	.25	.21	.25	.28
K ₂ O	.00	.01	.01	.02	.02	.02	.00
Total	100.17	100.89	100.47	100.08	99.37	99.74	100.20
Wo	39.5	42.2	42.3	42.5	41.9	37.9	43.8
En	43.7	44.2	44.2	47.2	47.2	48.2	42.6
Fs	16.7	13.7	13.5	10.3	10.9	13.9	13.6

Aug- 1~ 3: Joboshi (KH-16, No. 9 in Table 4)

4~ 6: Numanokawa 1 (KH-29, No. 22)

7~14: Kadono upper (KH-17, No. 53)

15: Omuroyama (KH-18, No. 46)

16~19: Komuroyama (KH-19, No. 42)

20~22: Ananokubo (KH-34, No. 37)

23: Iwanoyama (KH-11, No. 60)

(Continued)

Table 3

No.	Hyp-1 G	Hyp-2 G	Hyp-3 G	Hyp-4 G	Hyp-5 G	Hyp-6 G	Hyp-7 G	Hyp-8 G
SiO ₂	53.09	53.86	54.53	53.51	52.73	53.75	53.07	52.25
TiO ₂	.33	.26	.25	.23	.29	.19	.25	.25
Al ₂ O ₃	1.83	1.27	1.06	1.72	1.43	.82	.82	.94
FeO*	14.24	14.12	14.24	15.31	15.12	15.02	18.12	17.50
MnO	.35	.38	.37	.40	.43	.40	.41	.42
MgO	27.00	27.15	27.96	26.62	25.88	25.98	23.47	25.27
CaO	2.32	2.27	2.20	2.85	2.63	2.38	2.79	2.31
Na ₂ O	.06	.01	.01	.00	.00	.04	.02	.04
K ₂ O	.00	.00	.01	.01	.00	.00	.00	.01
Total	99.22	99.32	100.63	100.65	98.51	98.58	98.95	98.99
Wo	4.6	4.4	4.2	5.5	5.2	4.7	5.6	4.5
En	73.6	74.0	74.5	71.5	71.4	71.9	65.9	68.8
Fs	21.8	21.6	21.3	23.0	23.4	23.4	28.5	26.7

No.	Hyp-9 P	Hyp-10 P	Hyp-11 P	Hyp-12 P	Hyp-13 P	Hyp-14 P	Hyp-15 P	Hyp-16 P
SiO ₂	52.48	53.47	53.42	52.61	52.40	52.56	52.51	52.80
TiO ₂	.29	.27	.17	.29	.08	.07	.09	.09
Al ₂ O ₃	2.47	1.96	1.13	1.43	.74	.61	.62	.69
FeO*	14.35	13.31	15.15	15.62	20.55	20.93	19.69	20.02
MnO	.41	.39	.50	.46	2.21	2.14	1.46	1.72
MgO	28.24	28.72	27.53	27.69	23.84	23.56	25.13	24.98
CaO	1.68	1.52	1.50	1.54	.56	.52	.63	.45
Na ₂ O	.06	.06	.04	.07	.02	.01	.00	.02
K ₂ O	.00	.02	.03	.02	.00	.00	.00	.00
Total	99.98	99.72	99.47	99.73	100.40	100.40	100.13	100.77
Wo	3.2	2.9	2.9	3.0	1.1	1.1	1.2	.9
En	75.3	77.1	74.2	73.7	66.7	66.0	68.6	68.4
Fs	21.5	20.0	22.9	23.3	32.2	32.9	30.2	30.7

No.	Hyp-17 P
SiO ₂	54.31
TiO ₂	.07
Al ₂ O ₃	1.28
FeO*	19.02
MnO	1.72
MgO	23.72
CaO	.63
Na ₂ O	.00
K ₂ O	.03
Total	100.78
Wo	1.3
En	68.1
Fs	30.6

Hyp- 1~ 4: Joboshi (KH-16, No. 9 in Table 4)
5~ 7: Omurayama (KH-18, No. 46)
8: Komuroyama (KH-19, No. 42)
9~12: Ananokubo (KH-34, No. 37)
13~16: Iwanoyama (KH-11, No. 60)
17: Kawagodaira (KH-36, No. 58)

(Continued)

Table 3

No.	Pig-1 G	Pig-2 G	Pig-3 G	Pig-4 G
SiO ₂	52.00	52.08	51.59	50.84
TiO ₂	.45	.48	.44	.70
Al ₂ O ₃	1.02	1.11	1.07	1.06
FeO*	19.07	20.07	20.08	21.04
MnO	.51	.54	.52	.58
MgO	21.52	20.29	21.02	18.24
CaO	4.27	4.51	4.94	6.28
Na ₂ O	.07	.11	.09	.08
K ₂ O	.01	.00	.00	.00
Total	98.92	99.19	99.75	98.82
Wo	8.7	9.6	9.9	13.0
En	61.0	58.3	58.7	52.8
Fs	30.3	32.4	31.4	34.2

Pig-1, 2: Joboshi (KH-16, No. 9 in Table 4)

3: Sukumoyama (KH-13, No. 3)

4: Omuroyama (KH-18, No. 46)

No.	Hb-1 P	Hb-2 P	Hb-3 P	Hb-4 P	Hb-5 P
SiO ₂	43.13	43.67	48.93	42.37	42.44
TiO ₂	1.78	2.30	1.43	2.61	2.39
Al ₂ O ₃	11.02	10.32	6.30	11.25	10.77
FeO*	13.00	12.74	11.41	12.21	13.13
MnO	.33	.22	.40	.20	.21
MgO	14.83	15.19	17.20	14.32	14.32
CaO	11.06	10.94	11.18	11.05	11.30
Na ₂ O	2.23	2.09	1.46	2.30	2.18
K ₂ O	.26	.21	.22	.29	.30
Total	97.64	97.68	98.53	97.60	97.04

Hb-1~3: Iwanoyama (KH-11, No. 60 in Table 4)

4, 5: Kawagodaira (KH-36, No. 58)

No.	Cr-1 P	Cr-2 P	Cr-3 P	Cr-4 P	Cr-5 P	Cr-6 P	Cr-7 P	Cr-8 P
SiO ₂	.13	.16	.06	.06	.13	.10	.10	.16
TiO ₂	1.13	1.58	1.20	1.03	.60	3.90	3.93	5.62
Al ₂ O ₃	17.85	16.52	16.96	17.96	10.75	4.77	4.93	2.56
V ₂ O ₃	.31	.36	.29	.31	.16	.54	.53	.54
Cr ₂ O ₃	31.31	25.80	30.66	30.87	18.13	16.01	15.30	10.75
Fe ₂ O ₃ *	17.23	23.58	19.29	18.71	38.42	40.40	40.09	4.16
FeO	21.05 (36.56)	21.71 (42.93)	21.14 (38.50)	20.32 (37.16)	23.02 (57.60)	27.89 (64.25)	28.03 (64.92)	30.43 (70.17)
MnO	.08	.39	.48	.64	1.19	1.22	1.42	.79
MgO	9.14	8.76	8.92	9.41	5.88	4.18	4.07	3.49
CaO	—	—	—	—	—	.03	.02	.05
NiO	.19	.12	.06	.07	.18	—	—	—
Total	98.41	98.98	99.06	99.38	98.48	99.03	99.44	98.55

Cr-1~4: Kadono lower (KH-22, No. 52 in Table 4)

5~8: Chikubo (KH-20, No. 51)

9: Sukumoyama (KH-13, No. 3)

10~12: Omuroyama (KH-18, No. 46)

Oike-minami (No. 56), Inatori 1, 2 (Nos. 50, 51 respectively), Sekiguchi-gawa-joryu (No. 75), and Amagi Highland-higashi (No. 45) are grouped under Basalt II. These rocks are characterized by olivine, plagioclase and calcium-rich clinopyroxene phenocrysts.

These rocks are mostly moderately to extremely porphyritic (up to 30.2% in modal volume, as listed in Table 2). Euhedral to subhedral olivine phenocrysts are always present, showing normal compositional zoning. Several tiny grains of opaque or brown picotite are always included in olivine phenocrysts.

Plagioclase phenocrysts show an euhedral shape with a relatively broad core and narrow rim, exhibiting normal compositional zoning.

Calcium-rich clinopyroxene phenocrysts are euhedral-shaped and always exhibit normal compositional zoning.

Three groundmass assemblages are observed in these rocks. The first assemblage is composed of olivine, plagioclase, augite and ore (Numanokawa 1,3, Noborio-minami and Inatori 1). The second is composed of olivine, plagioclase, augite, pigeonite and ore (Yoichizaka, Hachikuboyama, Hontanigawa-shiryu, Maruyama, Hacchoyo-rindo, Marunoyama, Nagano, Hachiyama-higashioku, Hachiyama, and Inatori 2). The third is composed of olivine, plagioclase, augite, hypersthene, pigeonite and ore (Numanokawa 1, Odaira, Oike-minami, Amagi Highland-higashi). Sometimes a small amount of glass is observed in each groundmass.

The composition of olivine and plagioclase is presented in Fig. 4. The composition of pyroxenes is plotted in Fig. 5. Chemical analyses of minerals in the rocks of Numanokawa 1 are presented in Table 3.

Basalt III

The rock of Sekiguchi 1 (No. 46 in Fig. 2 and Table 1) is grouped under Basalt III, which is characterized by olivine, plagioclase, calcium-rich clinopyroxene and orthopyroxene phenocrysts assemblage. The groundmass is composed of olivine, plagioclase, augite, pigeonite, hypersthene and ore. The composition of olivine and plagioclase is presented in Fig. 4 and that of pyroxenes is plotted in Fig. 5.

Andesite I

The rocks of Komuroyama (No. 7 in Fig. 2 and Table 1), Chikubo (No. 16, 17), Kawana-minami (No. 8), Sannohara-kita (No. 9), Harai (No.32), Omuroyama (No. 19) and Iyuzan (No. 21) are classified under Andesite I. These rocks contain olivine phenocrysts and some do and some do not contain plagioclase phenocrysts.

Euhedral to subhedral olivine phenocrysts are always present.

Sporadic tiny grains of picotite are included in the olivine phenocrysts. Plagioclase phenocryst has a euhedral shape, usually showing normal compositional zoning. Some rocks lack plagioclase phenocrysts.

There are two groundmass assemblages observed in Andesite I. One is composed of plagioclase, augite, hypersthene, pigeonite and ore (Komuroyama, Harai, Omuroyama and Iyuzan) and the other is composed of plagioclase, augite, hypersthene and ore. In both cases parallel intergrowths of orthopyroxene and clinopyroxene are observed in the groundmass.

Liquid immiscibility is observed in the groundmass, evidenced by the presence of dark-colored spherical globules in light-colored glass matrix, especially in the rocks of Omuroyama (KH-18) and Komuroyama (KH-19) (FUJII *et al.*, 1980).

The rocks of Andesite I always contain xenocrysts of quartz, plagioclase (andesine), and sometimes hornblende or biotite and ore probably derived from granitic rocks. Quartz grain is surrounded by brown glass. This glass is interpreted to have been formed by the melting of quartz and its mixture with the surrounding basaltic liquid (SATO, 1977). Many small augite grains grow inward from the outer rim of the glass. Plagioclase xenocryst is surrounded by a zone of dusty inclusions and the outer most clear zone of various thickness, usually more calcic in composition. Xenocrysts of hornblende or biotite are completely replaced by the fine-grained aggregate of pyroxenes. Xenocryst of iron ore is sometimes accompanied with other xenocrysts described above. The modal volumes of xenocrysts reach 17%.

The composition of olivine and plagioclase is presented in Fig. 4 and the composition of pyroxenes is plotted in Fig. 5. The composition of minerals in the rocks of Omuroyama, Komuroyama are presented in Table 3.

Andesite II

The rocks of Togasayama (No. 37 in Fig. 2 and Table 1), Kadono (No. 11) are grouped under Andesite II. These rocks contain olivine, plagioclase and augite phenocrysts. Euhedral to subhedral olivine phenocrysts are present. The rocks from the upper flow of Kadono rarely contain olivine phenocryst. Tiny grains of picotite are always included within the olivine phenocrysts. Plagioclase phenocryst shows a euhedral shape with a relatively broad core and narrow rim, normal compositional zoning. Augite phenocryst shows a euhedral shape.

Two groundmass assemblages are observed in the rocks. The rocks of Togasayama and the lower lava of Kadono are composed of olivine, plagioclase, augite, hypersthene, pigeonite and ore. The rock

of the upper lava flow of Kadono is composed of plagioclase, augite, hypersthene and ore. These rocks also contain the same kind of xenocrysts described in the second on Andesite I.

The composition of olivine and plagioclase is presented in Fig. 4 and that of pyroxenes is plotted in Fig. 5.

Andesite III

The rocks of Akakubo (No. 30 in Fig. 2 and Table 1), Ananokubo (No. 24), Iwanokubo (Nos. 25 and 26), Sugehiki (No. 38) and Dainoyama (No. 20) are grouped under Andesite III. These rocks contain phenocrysts of olivine, plagioclase, augite and hypersthene.

Euhedral to subhedral olivine phenocryst is always contained except in the rock of Dainoyama. Tiny grains of picotite are included in olivine phenocryst. Plagioclase phenocryst shows an euhedral outline with a broad core and a narrow rim. Normal compositional zoning is observed in the plagioclase phenocryst. Augite and orthopyroxene phenocrysts show a euhedral shape.

The groundmass in the rock of Akakubo and Dainoyama is composed of plagioclase, augite, hypersthene and ore. The rocks of Iwanokubo and Ananokubo contain brown glass.

Xenocrysts of quartz and plagioclase are contained in the rocks of the Andesite III group. The rocks of Ananokubo and Iwanoyama rarely contain tiny crystals of brown hornblende, probably derived from a granitic xenolith.

Dacite I

The rocks of Kawagodaira (No. 43 in Fig. 2 and Table 1) contain crystals of plagioclase, orthopyroxene, hornblende, magnetite, ilmenite and rarely quartz. Except for minute rod-shaped microlites, the groundmass is composed of glass. Segregation of the microlites into bands is sometimes observed for the flow banding of the dacite.

Plagioclase phenocrysts (2.5 mm in maximum length) have anhedral zoned core indicating resorption and a relatively broad overgrown rim. The composition of plagioclase phenocryst, as determined by electron microprobe analysis, is presented in Fig. 3 and Table 3. The compositional range of the core is from An_{70} to An_{35} and that of the rim of plagioclase is similar to that of the core. Rounded quartz crystals are rarely observed in small amounts. Hornblende phenocryst (1.5 mm in maximum length) is euhedral brown hornblende, frequently including poikilitically small plagioclase crystals. Its composition is presented in Table 3. The orthopyroxene phenocrysts (1 mm in maximum length) are a euhedral lath-shaped crystals, frequently including crystals of

magnetite. Small amount of olivine, Ca-rich plagioclase (An_{65} to An_{85}) and augite crystals are rarely observed. They are probably xenocrysts.

Dacite II

The rocks of Iwanoyama, Ananoyama and Yahazuyama (Nos. 27, 23, 22 in Fig. 2 and Table 1 respectively) contain large crystals of plagioclase, orthopyroxene, hornblende, magnetite, ilmenite, olivine, clinopyroxene and rare quartz. Except for minute but abundant plagioclase and a lesser amount of orthopyroxene and hornblende crystals, the groundmass is composed of clear glass.

Two types of plagioclase are contained in dome lavas. One is euhedral plagioclase (An_{90}) with a broad core and a narrow rim. The other is anhedral plagioclase (An_{50}) with a relatively broad rim around the core. The composition of the rim of the second type plagioclase is similar to or more calcic than that of the core. This type of plagioclase is the same as that in Dacite I, while the former type is rarely found in Dacite I. The former type of plagioclase is probably a xenocryst. The composition of plagioclase determined by electron-microprobe analysis is presented in Fig. 4.

Hornblende phenocryst is euhedral brown hornblende, frequently including small plagioclase crystals poikilitically. The composition is presented in Table 3.

The orthopyroxene phenocryst is a euhedral-lath shaped crystal, frequently including euhedral crystals of magnetite and ilmenite. Weak reverse zoning is observed at the rim of orthopyroxene phenocryst.

Clinopyroxene is a euhedral crystal with 1 mm in length and olivine (Fo_{80} to Fo_{70}) is also euhedral, including minute grains of picotite. Minute grains of brown hornblende are observed around olivine crystals. A small amount of rounded quartz grain is rarely found. Large crystals of sodic plagioclase (An_{50}), hornblende, hypersthene, magnetite, ilmenite and quartz in Dacite II are identical in composition, size and shape with those in Dacite I. Large crystals of calcic plagioclase (An_{90}), olivine (Fo_{80-70}) with picotite inclusions and clinopyroxene are respectively identical to those of Basalt II and Andesite II. These facts suggest that the minerals of the latter group are xenocrysts derived from the basalt and andesite magma through magma mixing or from those rocks through mechanical contamination.

(Granitic xenolith)

A partly melted granitic xenolith is collected from the pyroclastic deposit of Iwanokubo-nishi crater (No. 26 in Fig. 2 and Table 1). The rock occurs as angular blocks 10 cm \times 5 cm \times 3 cm in size and contains

Table 4. Chemical composition of the rocks of the Higashi-Izu monogenetic volcano group. Wet chemical analyses by H. Haramura and X-ray fluorescence analyses.

No.	1	2	3	4	5	6	7	8
SiO ₂	49.64	48.90	49.02	50.55	50.21	51.25	49.08	49.08
TiO ₂	.94	.97	.89	.89	.99	.99	.90	.90
Al ₂ O ₃	18.27	17.58	18.10	18.08	17.86	17.95	17.65	17.58
Fe ₂ O ₃	4.21	2.47	1.68	3.58	3.87	10.08	2.33	2.78
FeO	5.95	8.00	8.25	6.89	6.02	.00	8.00	6.78
MnO	.15	.16	.16	.20	.17	.17	.25	.18
MgO	6.42	7.79	7.55	6.48	6.85	6.05	8.02	7.74
CaO	10.02	10.82	10.48	9.87	9.69	9.93	10.26	9.90
Na ₂ O	2.78	2.32	2.43	2.71	2.66	2.71	2.02	2.52
K ₂ O	.53	.27	.35	.29	.51	.42	.35	.36
H ₂ O ⁺	.76	.00	.71	.28	.61	.00	.00	.64
H ₂ O ⁻	.03	.00	.25	.22	.10	.00	.00	.02
P ₂ O ₅	.16	.09	.10	.30	.31	.20	.00	.41
Total	99.86	99.37	99.97	100.34	99.85	99.75	98.86	99.66
Ni	39		5	5				14
Cr	87	274	31	16				277
(ppm)								
CIPW NORM								
Q	.81	.00	.00	2.11	2.03		.00	.46
OR	3.13	1.60	2.07	1.71	3.01		2.07	2.13
AB	23.52	19.63	20.56	22.93	22.51		17.09	21.32
AN	35.81	36.76	37.45	36.31	35.29		38.06	35.59
WO	5.37	6.82	5.80	4.47	4.50		5.36	4.54
EN	15.99	15.21	13.01	16.14	17.06		18.76	19.28
FS	6.17	8.90	8.71	8.60	6.54		11.03	9.00
FO	.00	2.94	4.06	.00	.00		.85	.00
FA	.00	1.89	3.00	.00	.00		.55	.00
MT	6.10	3.58	2.44	5.19	5.61		3.38	4.03
HM	.00	.00	.00	.00	.00		.00	.00
IL	1.79	1.84	1.69	1.69	1.88		1.71	1.71
AP	.37	.21	.23	.69	.71		.00	.94

(Continued)

Table 4

No.	9	10	11	12	13	14	15	16
SiO ₂	50.02	51.23	50.91	50.13	49.83	50.56	49.52	51.85
TiO ₂	.98	1.09	1.08	1.02	.94	.91	.97	.97
Al ₂ O ₃	18.06	17.30	17.44	18.23	17.46	18.38	17.49	17.64
Fe ₂ O ₃	3.09	3.47	3.61	3.56	3.38	2.90	10.61	2.41
FeO	6.40	6.71	6.51	6.82	7.01	5.91	.00	6.25
MnO	.17	.17	.17	.18	.19	.18	.17	.15
MgO	7.75	6.85	6.88	5.84	7.13	6.80	7.77	6.16
CaO	10.05	9.92	9.63	10.25	10.24	10.46	9.95	10.58
Na ₂ O	2.46	2.71	2.62	2.53	2.38	2.57	2.37	3.07
K ₂ O	.40	.41	.39	.37	.46	.48	.41	.32
H ₂ O ⁺	.39	.40	.69	.43	.29	.38	.00	.36
H ₂ O ⁻	.02	.02	.29	.10	.10	.07	.00	.07
P ₂ O ₅	.39	.28	.24	.37	.30	.17	.16	.07
Total	100.18	100.56	100.46	99.83	99.71	99.77	99.42	99.90
Ni	56	8	4	<4	5	4		5
Cr	225	74	131	24	21	149		69
(ppm)								
CIPW NORM								
Q	.81	2.51	3.03	3.02	1.31	1.32		1.42
OR	2.36	2.42	2.30	2.19	2.72	2.84		1.89
AB	20.82	22.93	22.17	21.41	20.14	21.75		25.98
AN	37.05	33.83	34.67	37.29	35.60	37.20		33.41
WO	4.29	5.67	4.82	4.66	5.54	5.68		7.78
EN	19.30	17.06	17.13	14.54	17.76	16.94		15.34
FS	7.90	7.97	7.50	8.23	8.88	7.29		8.16
FO	.00	.00	.00	.00	.00	.00		.00
FA	.00	.00	.00	.00	.00	.00		.00
MT	4.48	5.03	5.23	5.16	4.90	4.20		3.49
HM	.00	.00	.00	.00	.00	.00		.00
IL	1.86	2.07	2.05	1.94	1.79	1.73		1.84
AP	.90	.65	.55	.85	.69	.89		.16

(Continued)

Table 4

No.	17	18	19	20	21	22	23	24
SiO ₂	51.61	50.81	48.31	50.24	50.09	48.96	49.54	51.11
TiO ₂	.92	1.08	1.17	1.01	.98	1.19	.99	.96
Al ₂ O ₃	18.87	17.92	18.54	17.29	18.52	16.36	17.62	18.15
Fe ₂ O ₃	1.31	3.52	4.67	3.93	2.64	2.55	4.73	3.11
FeO	6.63	5.87	5.02	5.13	5.94	6.82	4.99	6.36
MnO	.16	.17	.17	.15	.15	.16	.17	.17
MgO	6.71	6.11	7.13	7.39	6.49	8.54	7.36	6.19
CaO	9.42	10.80	10.60	11.13	11.25	11.49	10.88	10.83
Na ₂ O	3.03	3.06	2.94	2.71	2.68	2.85	2.72	2.71
K ₂ O	.46	.27	.18	.33	.27	.27	.24	.35
H ₂ O ⁺	.34	.29	.74	.33	.51	.28	.31	.18
H ₂ O ⁻	.02	.00	.20	.02	.00	.02	.02	.00
P ₂ O ₅	.21	.16	.20	.20	.21	.29	.19	.16
Total	99.69	100.06	99.87	99.86	99.73	99.78	99.76	100.28
Ni	7	35	55	66	36	<4	58	30
Cr	96	62	90	109	6	37	154	53
(ppm)								
CIPW NORM								
Q	.04	1.19	.00	1.02	.53	.00	1.05	1.99
OR	2.72	1.60	1.06	1.95	1.60	1.60	1.42	2.07
AB	25.64	25.89	24.88	22.93	22.68	24.12	23.02	22.93
AN	36.53	34.36	36.86	34.04	37.71	31.05	35.16	36.33
WO	3.69	7.59	6.03	8.30	6.99	10.05	7.34	6.83
EN	16.71	15.22	15.31	18.40	16.16	11.15	18.33	15.42
FS	9.87	6.40	3.23	4.78	7.39	4.59	3.94	7.84
FO	.00	.00	1.72	.00	.00	7.09	.00	.00
FA	.00	.00	.40	.00	.00	3.21	.00	.00
MT	1.90	5.10	6.77	5.70	3.83	3.70	6.86	4.51
HM	.00	.00	.00	.00	.00	.00	.00	.00
IL	1.75	2.05	2.22	1.92	1.86	2.26	1.88	1.82
AP	.48	.37	.46	.46	.48	.67	.44	.37

(Continued)

Table 4

No.	25	26	27	28	29	30	31
SiO ₂	52.99	51.68	50.24	50.65	49.32	50.41	52.43
TiO ₂	1.04	1.03	1.07	1.03	.92	1.03	.92
Al ₂ O ₃	17.54	17.84	19.64	17.87	17.62	17.00	16.90
Fe ₂ O ₃	3.57	3.11	2.98	3.44	3.34	4.22	3.14
FeO	5.11	5.71	5.82	5.49	6.25	5.90	6.13
MnO	.16	.16	.15	.17	.17	.19	.17
MgO	5.18	6.20	6.33	6.18	7.00	6.45	6.08
CaO	9.88	10.94	9.81	11.21	12.22	10.80	9.44
Na ₂ O	3.43	2.91	3.21	3.01	2.36	2.87	2.73
K ₂ O	.49	.29	.26	.24	.27	.43	.62
H ₂ O ⁺	.17	.30	.32	.32	.54	.39	.89
H ₂ O ⁻	.02	.02	.00	.02	.00	.03	.25
P ₂ O ₅	.29	.26	.03	.28	.14	.28	.13
Total	99.87	100.45	99.86	99.91	100.15	100.00	99.83
Ni	<4	<4	35	42	41	40	41
Cr	31	14	48	132	119	61	106
(ppm)							
CIPW NORM							
Q	4.28	2.57	.00	1.27	.00	1.58	4.87
OR	2.90	1.71	1.54	1.42	1.60	2.54	3.66
AB	29.02	24.62	27.16	25.47	19.97	24.29	23.10
AN	31.02	34.76	38.41	34.54	36.69	32.23	32.03
WO	6.73	7.45	4.28	8.04	9.62	8.16	5.83
EN	12.90	15.44	13.91	15.39	17.14	16.06	15.14
FS	5.01	6.51	5.94	5.85	7.39	6.00	7.46
FO	.00	.00	1.03	.00	.21	.00	.00
FA	.00	.00	.61	.00	.10	.00	.00
MT	5.18	4.51	4.32	4.99	4.84	6.12	4.55
HM	.00	.00	.00	.00	.00	.00	.00
IL	1.98	1.96	2.03	1.96	1.75	1.96	1.75
AP	0.67	.60	.00	.65	.32	.65	.30

(Continued)

Table 4

No.	32	33	34	35	36	37	38	39
SiO ₂	51.62	49.45	54.73	57.32	54.87	56.01	53.26	54.12
TiO ₂	1.04	.85	.72	.77	.76	.85	.87	.85
Al ₂ O ₃	18.25	17.71	18.11	17.16	17.27	16.88	18.01	17.90
Fe ₂ O ₃	2.17	3.48	2.97	3.01	3.93	3.70	2.57	2.28
FeO	6.55	5.90	4.88	4.61	3.95	4.99	6.38	6.53
MnO	.15	.17	.14	.13	.14	.17	.18	.20
MgO	5.84	7.16	4.95	4.48	5.20	3.98	5.58	5.61
CaO	10.23	12.66	9.65	8.15	9.35	7.78	8.26	8.24
Na ₂ O	3.19	2.18	2.72	3.02	2.59	3.16	2.55	2.78
K ₂ O	.41	.29	.57	.81	.73	.96	.72	.77
H ₂ O ⁺	.34	.31	.20	.25	.56	1.12	1.00	.53
H ₂ O ⁻	.12	.00	.05	.05	.00	.05	.27	.19
P ₂ O ₅	.14	.13	.19	.02	.29	.13	.23	.22
Total	100.05	100.29	99.88	99.78	99.64	99.78	99.88	100.22
Ni	26	57	4	30	42	10		
Cr	27	163	46	86	10	8		
(ppm)								
CIPW NORM								
Q	.62	.34	9.06	12.35	11.08	11.31	7.28	6.62
OR	2.42	1.71	3.37	4.79	4.31	5.67	4.25	4.55
AB	26.99	18.45	23.02	25.55	21.92	26.74	21.58	23.52
AN	34.27	37.68	35.52	30.87	33.34	29.04	35.57	34.09
WO	6.50	10.14	4.64	3.94	4.66	3.64	1.64	2.24
EN	14.54	17.83	12.33	11.16	12.95	9.91	13.90	13.97
FS	8.80	6.87	5.58	4.95	3.01	5.02	8.49	9.08
FO	.00	.00	.00	.00	.00	.00	.00	.00
FA	.00	.00	.00	.00	.00	.00	.00	.00
MT	3.15	5.05	4.31	4.36	5.70	5.36	3.73	3.31
HM	.00	.00	.00	.00	.00	.00	.00	.00
IL	1.98	1.61	1.37	1.46	1.44	1.61	1.65	1.61
AP	.32	.30	.44	.05	.67	.30	.53	.51

(Continued)

Table 4

No.	40	41	42	43	44	45	46	47
SiO ₂	58.02	57.05	53.14	55.12	53.76	55.22	54.88	55.62
TiO ₂	.72	.75	.86	.85	1.11	.85	.80	.86
Al ₂ O ₃	16.94	17.49	19.31	15.46	18.34	16.96	17.08	16.91
Fe ₂ O ₃	2.12	1.67	2.88	5.88	2.12	3.08	3.35	2.02
FeO	5.08	5.75	4.99	3.60	6.28	4.84	4.95	6.24
MnO	.17	.13	.15	.15	.26	.15	.14	.14
MgO	4.31	4.59	4.46	5.87	5.25	5.52	5.95	5.87
CaO	6.86	7.47	9.02	8.66	7.96	8.61	8.45	8.63
Na ₂ O	3.40	3.17	3.14	2.94	2.89	3.04	2.83	2.98
K ₂ O	1.05	.90	.81	.76	.71	.75	.76	.72
H ₂ O ⁺	.80	.46	.45	.23	.79	.42	.31	.35
H ₂ O ⁻	.24	.05	.15	.00	.19	.00	.02	.05
P ₂ O ₅	.19	.28	.29	.22	.31	.27	.24	.24
Total	99.90	99.76	99.65	99.74	99.97	99.71	99.76	100.63
Ni		17	8	60		11	5	
Cr		96	10	98		110	128	
(ppm)								
CIPW NORM								
Q	11.65	10.33	5.48	11.33	6.92	8.65	8.69	7.32
OR	6.20	5.32	4.79	4.49	4.20	4.43	4.49	4.25
AB	28.77	26.82	26.57	24.88	24.45	25.72	23.95	25.22
AN	27.86	30.84	36.20	26.74	34.97	30.42	31.66	30.64
WO	2.06	1.84	2.79	6.18	1.05	4.41	3.64	4.44
EN	10.73	11.43	11.11	14.62	13.08	13.75	14.82	14.62
FS	6.70	8.18	5.64	.63	8.43	5.22	5.26	8.63
FO	.00	.00	.00	.00	.00	.00	.00	.00
FA	.00	.00	.00	.00	.00	.00	.00	.00
MT	3.07	2.42	4.18	8.53	3.07	4.47	4.86	2.93
HM	.00	.00	.00	.00	.00	.00	.00	.00
IL	1.37	1.42	1.63	1.61	2.11	1.61	1.52	1.63
AP	.44	.65	.67	.51	.71	.62	.55	.55

(Continued)

Table 4

No.	48	49	50	51	52	53	54	55
SiO ₂	53.63	52.26	53.66	53.80	54.42	53.75	54.38	53.55
TiO ₂	.86	.77	.89	.77	.82	.85	.90	.89
Al ₂ O ₃	17.41	17.63	18.31	16.82	17.85	18.31	17.00	17.31
Fe ₂ O ₃	4.38	3.69	3.08	4.18	3.43	3.43	3.85	3.83
FeO	4.34	6.36	5.07	4.08	4.49	4.72	4.43	4.61
MnO	.41	.17	.14	.13	.14	.14	.14	.15
MgO	5.78	5.41	4.65	6.02	5.04	4.64	6.04	6.26
CaO	9.36	9.34	9.44	9.81	9.02	9.38	8.48	8.23
Na ₂ O	2.74	2.94	2.96	2.54	2.98	2.97	3.04	2.79
K ₂ O	.56	.38	.62	.62	.71	.68	.77	.71
H ₂ O ⁺	.24	.87	.51	.63	.52	.70	.40	.90
H ₂ O ⁻	.07	.39	.20	.15	.05	.02	.25	.48
P ₂ O ₅	.17	.19	.22	.20	.21	.19	.17	.19
Total	99.68	100.40	99.75	99.75	99.68	99.78	99.77	99.90
Ni	60		12	57	9	9	80	82
Cr	96		37	113	33	28	154	92
(ppm)								
CIPW NORM								
Q	8.44	5.11	7.28	9.02	8.34	7.56	7.68	7.81
OR	3.31	2.25	3.66	3.66	4.20	4.02	4.55	4.20
AB	23.19	24.88	25.05	21.49	25.22	25.13	25.72	23.61
AN	33.55	33.79	34.84	32.66	33.23	34.62	30.47	32.61
WO	4.92	4.73	4.41	6.14	4.24	4.46	4.39	2.92
EN	14.40	13.47	11.58	14.99	12.55	11.56	15.07	15.59
FS	3.19	7.68	5.56	3.01	4.32	4.69	3.56	4.11
FO	.00	.00	.00	.00	.00	.00	.00	.00
FA	.00	.00	.00	.00	.00	.00	.00	.00
MT	6.35	5.35	4.47	6.06	4.97	4.97	5.58	5.55
HM	.00	.00	.00	.00	.00	.00	.00	.00
IL	1.63	1.46	1.69	1.46	1.56	1.61	1.71	1.69
AP	.39	.44	.51	.46	.48	.44	.39	.44

(Continued)

Table 4

No.	56	57	58	59	60	61	62	63
SiO ₂	59.44	72.96	72.75	71.10	69.21	70.63	67.91	74.58
TiO ₂	.81	.31	.32	.36	.37	.33	.44	.26
Al ₂ O ₃	16.23	13.36	13.43	13.73	15.70	14.21	15.07	13.44
Fe ₂ O ₃	3.23	1.98	1.51	1.45	1.38	1.58	2.17	2.03
FeO	3.39	.53	.99	1.60	1.29	1.37	1.61	.00
MnO	.13	.07	.07	.08	.10	.07	.09	.05
MgO	3.59	.78	.80	1.33	1.24	1.15	1.40	.56
CaO	7.73	2.54	2.51	3.58	3.90	3.52	4.10	2.25
Na ₂ O	3.44	4.12	4.11	3.81	3.72	3.76	3.78	4.04
K ₂ O	1.21	2.58	2.61	2.08	2.09	2.28	2.05	3.04
H ₂ O ⁺	.18	.36	.48	.48	.60	.67	.90	.00
H ₂ O ⁻	.02	.00	.00	.02	.05	.07	.07	.00
P ₂ O ₅	.30	.08	.05	.16	.13	.10	.17	.04
Total	99.70	99.67	99.63	99.78	99.78	99.74	99.76	100.29
Ni	6	<3	<3	4	4	11	5	
Cr	11	<5	<5	10	12	6	4	
(ppm)								
CIPW NORM								
Q	15.01	33.12	32.70	31.72	29.37	31.05	27.65	
OR	7.15	15.25	15.42	12.29	12.35	13.47	12.11	
AB	29.11	34.86	34.78	32.24	31.48	31.82	31.99	
AN	25.27	10.34	10.49	14.22	18.51	15.16	18.10	
WO	4.65	.73	.69	1.05	.00	.69	.48	
EN	8.94	1.94	1.99	3.31	3.09	2.86	3.49	
FS	2.46	.00	.17	1.29	.80	.80	.60	
FO	.00	.00	.00	.00	.00	.00	.00	
FA	.00	.00	.00	.00	.00	.00	.00	
MT	4.68	1.04	2.19	2.10	2.00	2.29	3.15	
HM	.00	1.26	.00	.00	.00	.00	.00	
IL	1.54	.54	.61	.68	.70	.63	.84	
AP	.69	.18	.12	.37	.30	.23	.39	

Table 4

No.	Locality	No.	Locality
1	Takatsukayama (KH-38)	33	Amagi Highland-higashi (KH-45)
2	Sukumoyama (Kuno, 1968)	34	Akukubo (KH-7)
3	Sukumoyama (KH-13)	35	Iyuzan (KH-14)
4	Hachigakubo (Kuno, 1962)	36	Ananokubo (KH-34)
5	Hachigakubo scoria (KH-15)	37	Iwanokubo (KH-33)
6	Uchino (KH-10)	38	Komuroyama (Kuno, 1954)
7	Joboshi (Kuno, 1954)	39	Komuroyama (Kuno, 1954)
8	Joboshi (KH-16A)	40	Komuroyama (Kuno, 1954)
9	Joboshi (KH-16B)	41	Komuroyama (KH-19)
10	Funabara (KH-23)	42	Kawana-minami (KH-2)
11	Funabara (KH-24)	43	Sannohara-kita (KH-21)
12	Jizodo 1 (KH-28)	44	Omuroyama (Kuno, 1954)
13	Jizodo 2 (KH-5)	45	Omuroyama (KH-18)
14	Nagano (KH-3)	46	Omuroyama (KH-51)
15	Marunoyama (KH-6)	47	Omuroyama (Kuno, 1965)
16	Yoichizaka (KH-9)	48	Harai (KH-35)
17	Hachikuboyama (KH-4)	49	Chikubo (Kuno, 1962)
18	Hontanigawa-shiryu (KH-44)	50	Chikubo (KH-20)
19	Maruyama (KH-32)	51	Kadono lower (KH-22)
20	Hachyo-rindo (KH-27)	52	Kadono upper (KH-17A)
21	Noborio-minami (KH-31)	53	Kadono upper (KH-17B)
22	Numanokawa 1 (KH-29)	54	Sugehiki (KH-48)
23	Numanokawa 2 (KH-40)	55	Togasayama (KH-49)
24	Numanokawa 3 (KH-41)	56	Dainoyama (KH-8)
25	Odaira (KH-26)	57	Kawagodaira (KH-36)
26	Hachiyama-higashioku (KH-25)	58	Kawagodaira (KH-37)
27	Hachiyama (KH-39-2)	59	Iwanoyama (KH-11)
28	Oike-minami (KH-30)	60	Iwanoyama (KH-12)
29	Inatori 1 (KH-42)	61	Ananoyama (KH-50)
30	Inatori 2 (KH-43)	62	Yahazuyama (KH-52)
31	Sekiguchi 1 (KH-47)	63	Iwanokubo xenolith (KH-53)
32	Sekiguchigawa-joryu (KH-46)		

quartz, plagioclase, opaque and glass.

Plagioclase (4 mm in maximum length) shows an anhedral outline. Oscillatory zoning is observed in the core of plagioclase. This plagioclase is frequently surrounded by plagioclase of beehive texture. The composition of plagioclase is presented in Fig. 4. Quartz (3 mm in maximum length) shows an anhedral outline (round and embayed) due to resorption. Lath-shaped aggregates of opaque minerals (1 mm in maximum length) are observed. Probably this is a hornblende replaced

Table 5. Chemical composition of the rocks of Omuroyama and Komuroyama. Analyzed by X-ray fluorescence.

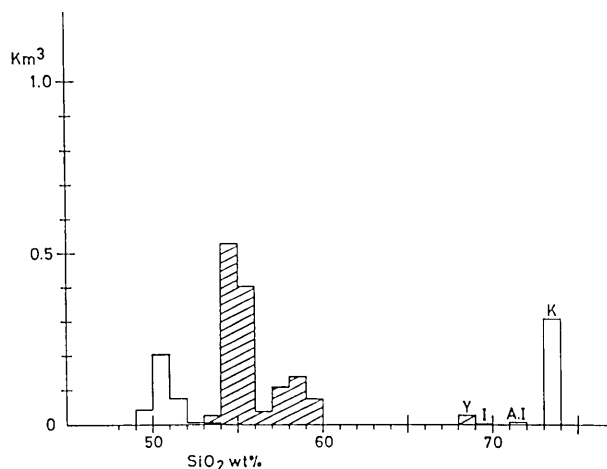
	O-1	O-2	O-3	O-4	O-5	O-6	O-7	
SiO ₂	55.63	55.46	55.22	54.95	55.41	54.40	54.66	
TiO ₂	.83	.87	.88	.89	.87	.91	.89	
Al ₂ O ₃	17.23	17.20	17.17	17.28	16.83	17.42	16.84	
Fe ₂ O ₃	8.56	8.59	8.61	8.45	8.38	8.79	8.95	
MnO	.14	.15	.14	.15	.14	.15	.15	
MgO	5.32	5.45	5.26	5.04	5.22	4.94	5.48	
CaO	8.84	8.84	8.79	9.27	8.61	9.66	8.74	
Na ₂ O	2.95	3.13	3.04	3.17	3.09	2.86	3.10	
K ₂ O	.74	.73	.76	.70	.73	.62	.72	
P ₂ O ₅	.21	.27	.23	.26	.23	.23	.24	
Total	100.50	100.69	100.10	100.16	99.51	99.98	99.77	
	O-8	O-9	O-10	O-11	O-12	O-13	O-14	
SiO ₂	54.28	55.04	54.42	54.39	55.04	54.55	54.89	
TiO ₂	.91	.93	.92	.90	.87	.88	.90	
Al ₂ O ₃	17.08	17.21	17.19	17.50	17.10	17.06	17.45	
Fe ₂ O ₃	8.91	8.63	8.59	8.71	8.45	8.68	8.69	
MnO	.15	.15	.15	.15	.15	.15	.15	
MgO	5.75	5.61	5.42	5.02	5.59	5.48	4.77	
CaO	8.87	8.42	8.61	9.90	8.94	9.11	9.44	
Na ₂ O	2.98	3.27	3.37	2.90	3.09	3.14	3.07	
K ₂ O	.73	.77	.76	.60	.71	.70	.67	
P ₂ O ₅	.22	.21	.24	.18	.26	.24	.23	
Total	99.88	100.24	99.67	100.25	100.10	99.99	100.26	
	K-1	K-2	K-3	K-4	K-5	K-6	K-7	K-8
SiO ₂	58.29	58.39	58.60	56.64	57.95	58.55	59.07	59.13
TiO ₂	.74	.74	.76	.77	.73	.75	.72	.72
Al ₂ O ₃	17.19	17.17	16.55	17.14	16.65	17.12	16.92	17.01
Fe ₂ eO ₃	7.58	7.63	7.61	8.21	7.80	7.81	7.59	7.64
MnO	.13	.13	.13	.13	.13	.13	.13	.13
MgO	3.79	3.75	3.99	4.25	4.48	4.00	4.07	4.16
CaO	7.69	7.55	7.70	8.39	7.91	7.77	7.49	7.68
Na ₂ O	3.27	3.16	3.22	2.76	3.14	3.11	3.02	2.86
K ₂ O	1.06	1.05	1.10	.92	1.10	1.00	1.13	1.11
P ₂ O ₅	.13	.13	.11	.17	.11	.12	.14	.15
Total	99.87	99.69	99.77	99.38	100.00	100.36	100.28	100.59

by opaque minerals. Individual grains of opaque minerals (0.3 mm) are also observed. Clear glass produced by partial melting surrounds these crystals. Glass accounts for about 50% of the total volume. Other tiny granitic xenoliths that were collected from the same described above showed no melting feature contain quartz, plagioclase and biotite.

(Continued)

Table 5

O-1:	(KH74052703) Totari Nokyo.
O-2:	(KH74052702) North of a golf course near Omuroyama.
O-3:	(KH74060201) Villa near Omuroyama.
O-4:	(KH74041106) South of Takamuroyama.
O-5:	(KH74032305) Hikarinomura, 1.5 km east of Omuroyama.
O-6:	(KH74032505) Harai Harber.
O-7:	(KH74032004) 400 m south of Cosmoland.
O-8:	(KH74041002) Kadowakizaki.
O-9:	(KH74041003) Marine Park.
O-10:	(KH74041102) South of Nichiranji.
O-11:	(KH74041103) North of Izu-kogen station.
O-12:	(KH74041201) Near Tajima Junior Highschool.
O-13:	(KH74052701) Old quarry near Ike.
O-14:	(KH74032306) North of Tajima Junior Highschool.
K-1:	(KH74030102) East of Kawana.
K-2:	(KH74031307) Kawana Lighthouse.
K-3:	(KH74031301) north of Ito Youthhostel.
K-4:	(KH74031601) Near Ogiya.
K-5:	(KH74031401) East of Yoshida.
K-6:	(KH74031309) Near the entrance of Kawana Hotel.
K-7:	(KH74031402) West of Kawana Golf Course.
K-8:	(KH74031202) 50 m north of Ito Commerical Highschool.


 Fig. 6. Bar diagram showing the relation between the SiO₂ content and the volume of the erupted materials.

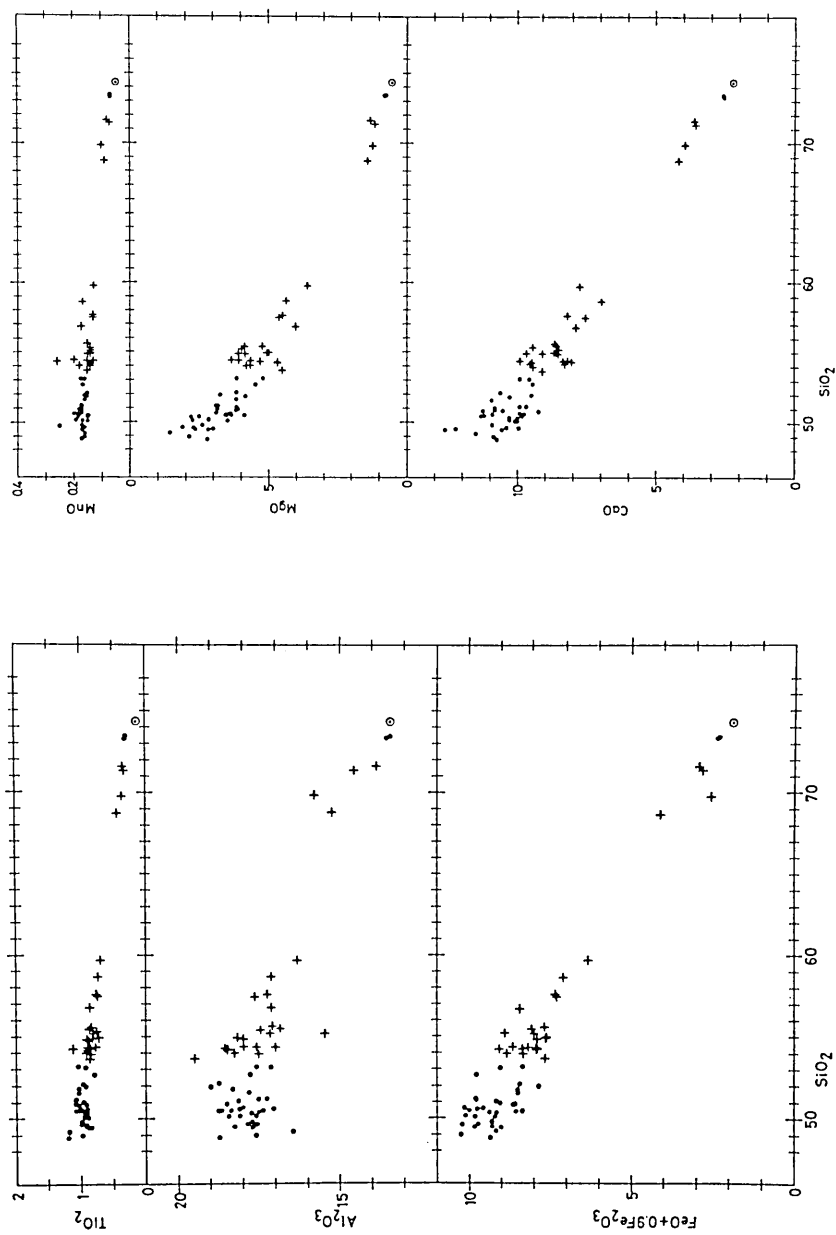
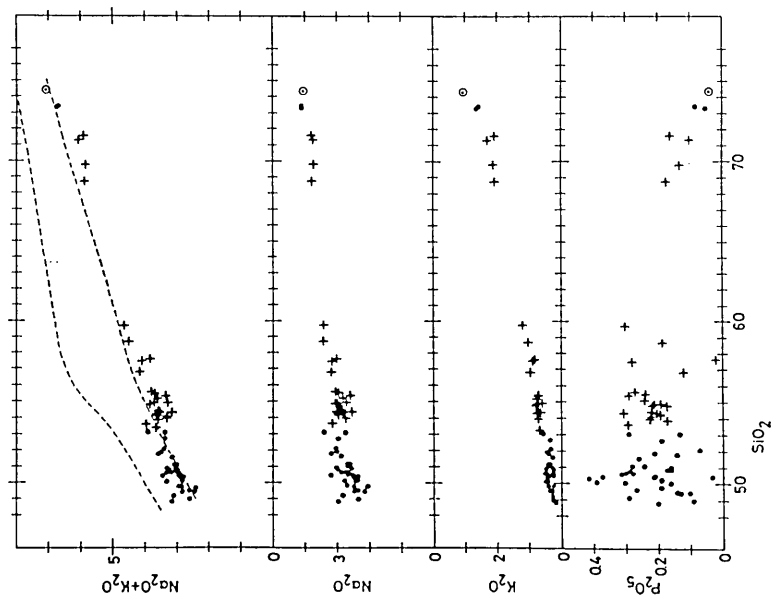
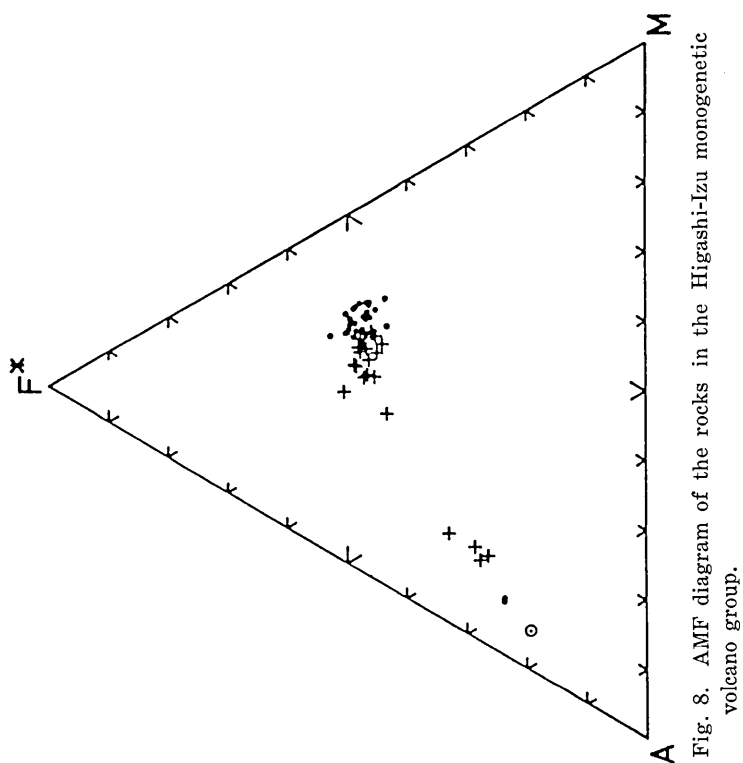


Fig. 7. SiO_2 variation diagrams in the rocks from the Higashi-Izu monogenetic volcano group. Dots indicate the rocks not containing xenocrysts and crosses indicate those containing xenocrysts. The Dotted circle corresponds to a granitic xenolith collected from the deposit at Iwanokubo.



III. Chemistry

(a) Major elements

Chemical compositions of eighty-three rocks from this volcano group were newly obtained by the wet chemical analysis (Analyst H. HARAMURA) and partly by the X-ray fluorescence analysis. Chemical compositions are listed in Tables 4 and 5.

The SiO_2 content of these rocks shows the bimodal distribution, i.e., separated into the range from 49 to 60 wt.% and the range from 68 to 74 wt.%. The relation between the SiO_2 content and the volume of the erupted materials of this volcano group is shown in Fig. 6. Large proportions of basic rocks and acidic rocks comprise the materials of Omuroyama and Komuroyama (Nos. 19 and 7 in Fig. 2 and Table 1) and that of Kawagodaira (No. 43) respectively. Bars containing oblique lines correspond to the materials with xenocrysts as described in the previous section. This suggests that these materials may be derived by contamination.

The SiO_2 variation diagrams for major elements and the AMF diagram of these rocks are shown in Figs. 7 and 8 respectively. Dots correspond to the rocks not containing xenocrysts (Basalt I, II, III) and crosses indicate those containing xenocrysts (Andesite I, II, III and Dacite II). A large dotted circle corresponds to a granitic xenolith collected from the deposit at Iwanokubo. The content of each major oxide changes almost linearly with the SiO_2 content. In general, MgO , CaO , Al_2O_3 , total Fe as FeO , TiO_2 and P_2O_5 decrease and Na_2O and K_2O increase with SiO_2 . The rocks containing xenocrysts are distributed in the SiO_2 -rich part of basic rocks and the SiO_2 -poor part of acidic rocks. The Al_2O_3 content of the rocks is higher (16 to 20 wt.%) for the basic group. While some rocks contain abundant plagioclase phenocrysts, the aphyric rocks also have a higher Al_2O_3 content as pointed by KUNO (1960), such as Sukumoyama (KH-13) and Joboshi (KH-16). The Na_2O content of the rocks from this volcano group is higher than that of Oshima "tholeiite" defined by KUNO (1960), though the K_2O content is similar in both cases (HAMURO *et al.*, 1980, 1983). Most of the basaltic rocks from this volcano group are distributed within the field of "the high-alumina basalt series" and the rest in "the tholeiitic rock series" in the SiO_2 vs. total alkali diagram defined by KUNO (1968) (Fig. 7). Within the basalts, the Na_2O , CaO and Al_2O_3 contents of Basalt I are slightly lower and the FeO^* contents of Basalt I are slightly higher than those of Basalt II even though some overlapping (e.g. Figs. 9-1, 9-2). However some of Basalt II (Inatori 1

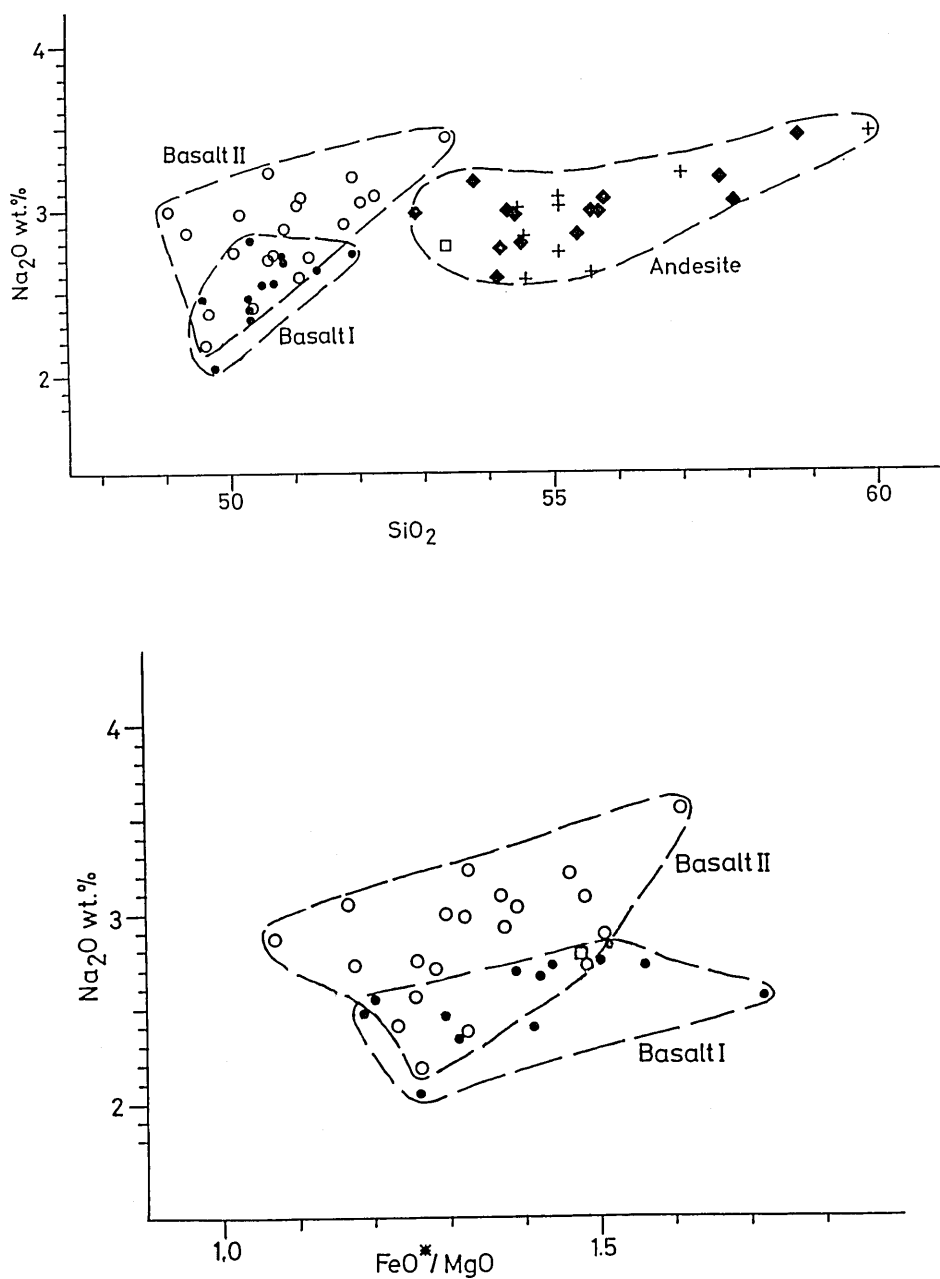


Fig. 9. SiO₂ variation diagram for Na₂O and FeO*/MgO diagrams for Na₂O and CaO of basalts in the Higashi-Izu monogenetic volcano group. Dots indicate Basalt I and open circles indicate Basalt II. Solid squares indicate Andesite I and crosses indicate Andesite II. Open square indicates Andesite III.

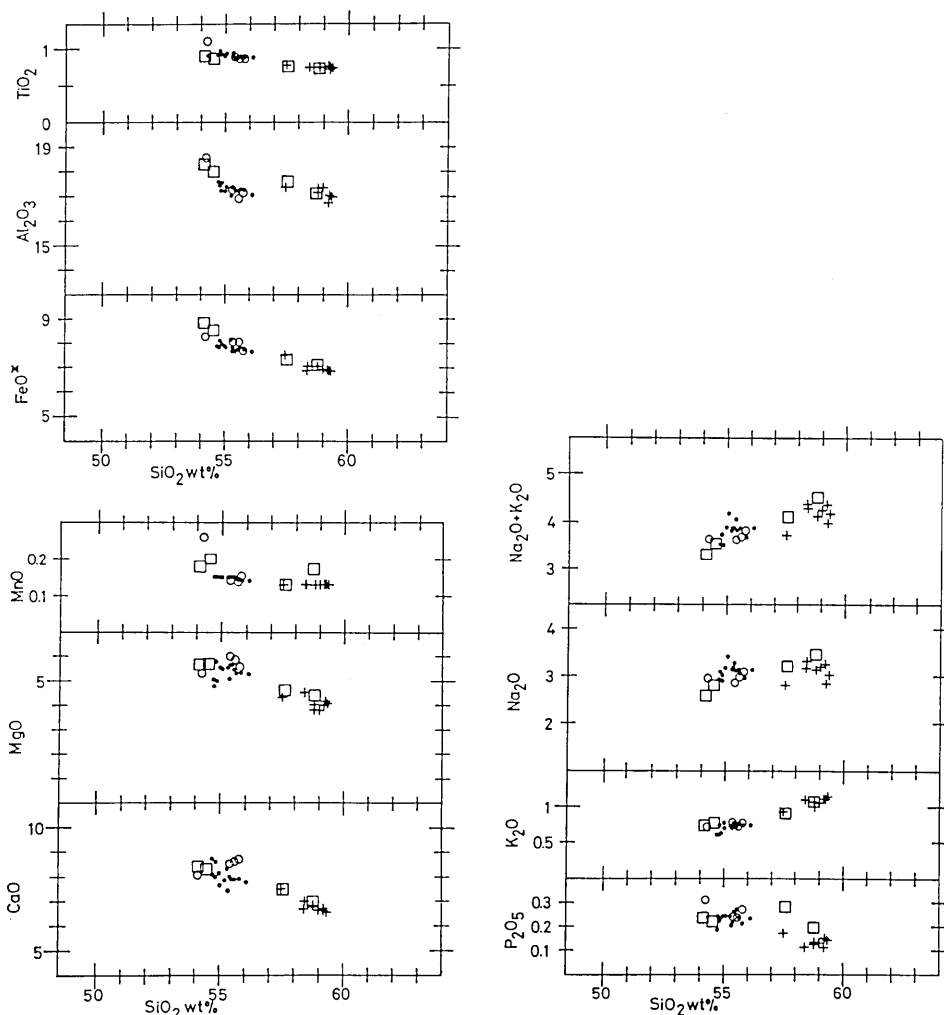


Fig. 10. SiO₂ variation diagrams in the rocks of Omuroyama and Komuroyama from the Higashi-Izu monogenetic volcano group. Dots indicate the rocks of Omuroyama and crosses indicate those of Komuroyama (X-ray fluorescence analyses). Open circles indicate the rocks of Omuroyama and open squares indicate those of Komuroyama (wet chemical analyses).

(KH-42), Amagi Highland-higashi (KH-45) and Marunoyama (KH-6)) show a lower Na₂O content that corresponds to those of Basalt I. Andesites seem to be plotted as the extrapolation of the Basalt I field. Most of andesites are olivine andesite with xenocrysts (Andesite I) as described previously. This relation also seems to imply that most of the andesites were derived from Basalt I mainly by contamination.

The SiO₂ variation diagram of fourteen analyses of rocks selected

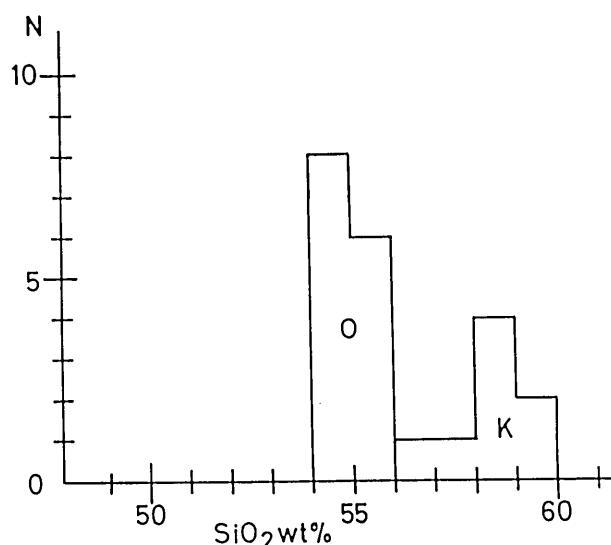


Fig. 11. SiO₂ variations in the rocks of Omuroyama and Komuroyama.

from Omuroyama lavas and eight from Komuroyama lavas is shown in Figs. 10 and 11. These selected rocks represent that extent of variation within the lava flows of Omuroyama and those of Komuroyama. These two volcanoes issued more than half of the materials erupted from this volcano group, so it is important to know the variation of the erupted materials in each volcano. These data indicate a relatively narrow but appreciable compositional variation of lavas from a vent. This is in strong contrast to the very small variation range in SiO₂ found in recent low-alkali tholeiitic basalt lava flows of Oshima volcano (IWASAKI *et al.*, 1960). The content of each major oxide changes almost linearly with the SiO₂ content, though the variation in SiO₂ content is not so large. Squares with 54 wt.% and 59 wt.%

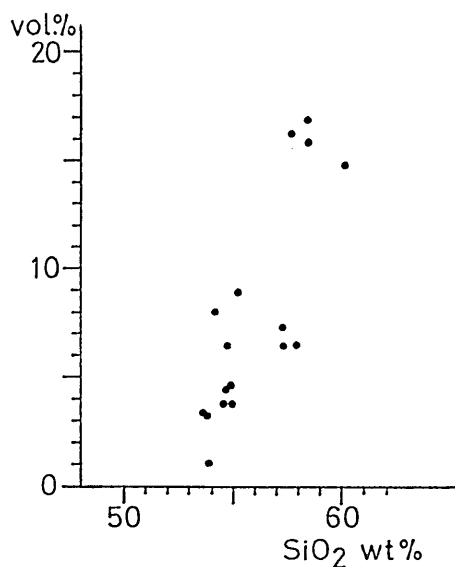


Fig. 12. SiO₂ content versus modal volume of xenocrysts contained in the andesites of Omuroyama, Komuroyama, Iyuzan, Chikubo, Kawanaminami and Harai.

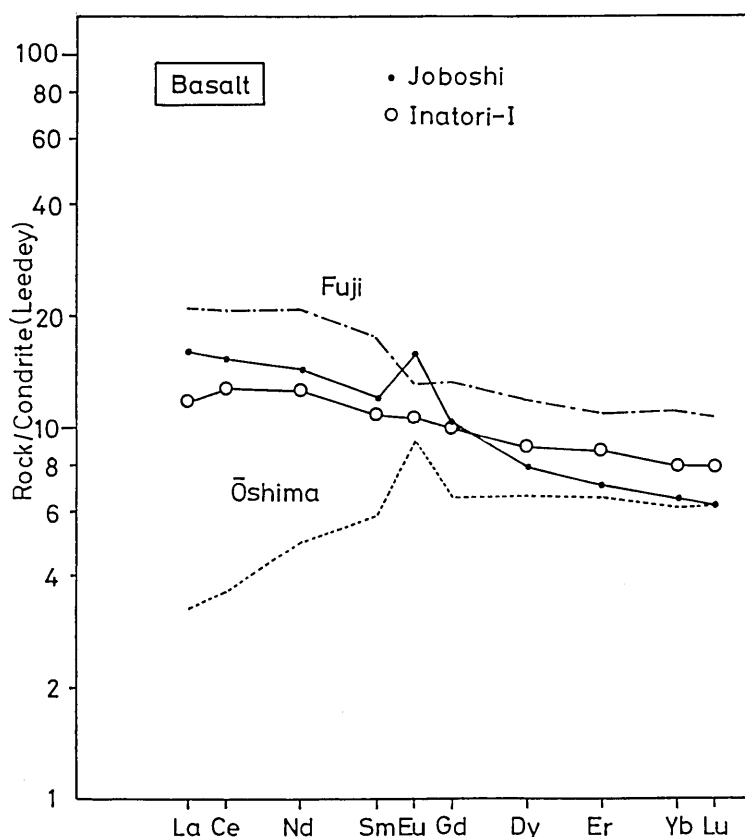


Fig. 13(A)

of SiO_2 content are those containing a small amount of xenocrysts and those with a considerable amount of xenocrysts collected in the same locality respectively (KUNO, 1954). This suggests that the increase of the amount of xenocrysts. Positive correlation between the SiO_2 content and the modal volume of xenocrysts as shown in Fig. 12 also lends support to this variation being caused by the contamination of granitic materials.

(b) Trace elements (REE, Ni and Cr)

The rare earth elements of eight rock samples from this volcano group were measured by H. FUJIMAKI with the isotope dilution method described in FUJIMAKI (1977). The measured samples contain two basalts, two andesites, two dacites and one granitic xenolith. Results are listed in Table 6 and the chondrite-normalized patterns are shown in Fig. 13.

Two basalt samples (Joboshi and Inatori 1) have different pheno-

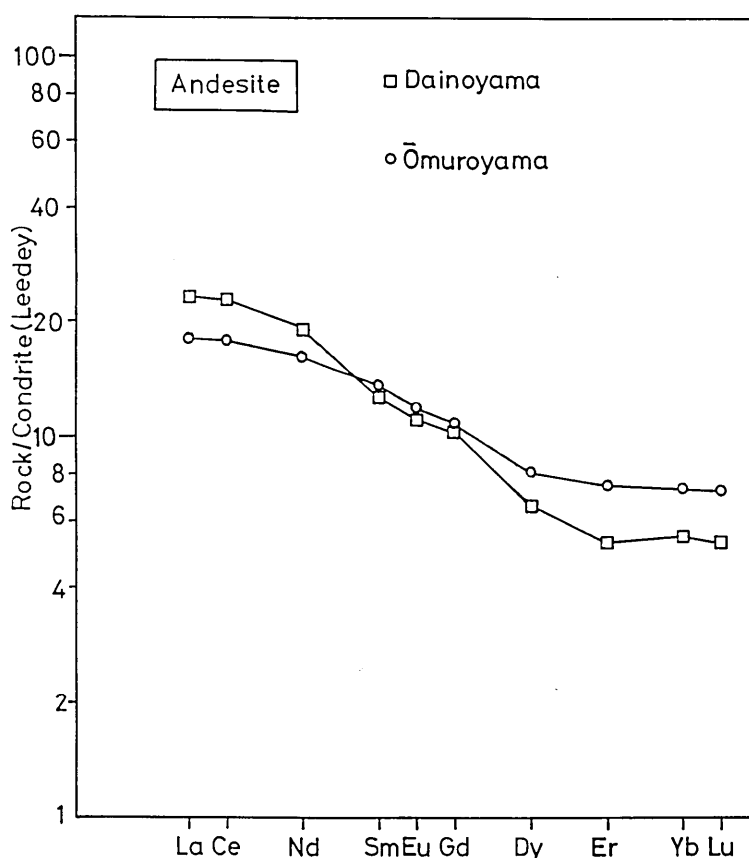


Fig. 13(B)

cryst assemblages; Ol+Pl (Basalt I) and Ol+Pl+Cpx (Basalt II). Both patterns show the relative enrichment of the light rare earth elements (LREE) to the heavy rare earth elements (HREE), the typical pattern for the high-alumina basalt of Japanese volcanoes (FUJIMAKI, 1977). However the two patterns show slightly different slopes. Joboshi has a positive Eu anomaly, suggesting a certain involvement of plagioclase while no petrographical indication is observed. The pattern of the Sukumoyama sample (Basalt I) measured by PHILPOTTS *et al.* (1971) shows a slightly lower content but a similar pattern to that of Joboshi.

Two andesites (Omuroyama and Dainoyama) show relative enrichment of the LREE similar to that in basalts. However Dainoyama andesite except Omuroyama shows less enrichment of the HREE than seen in basalts.

The chondrite-normalized patterns of two dacites (Iwanoyama and

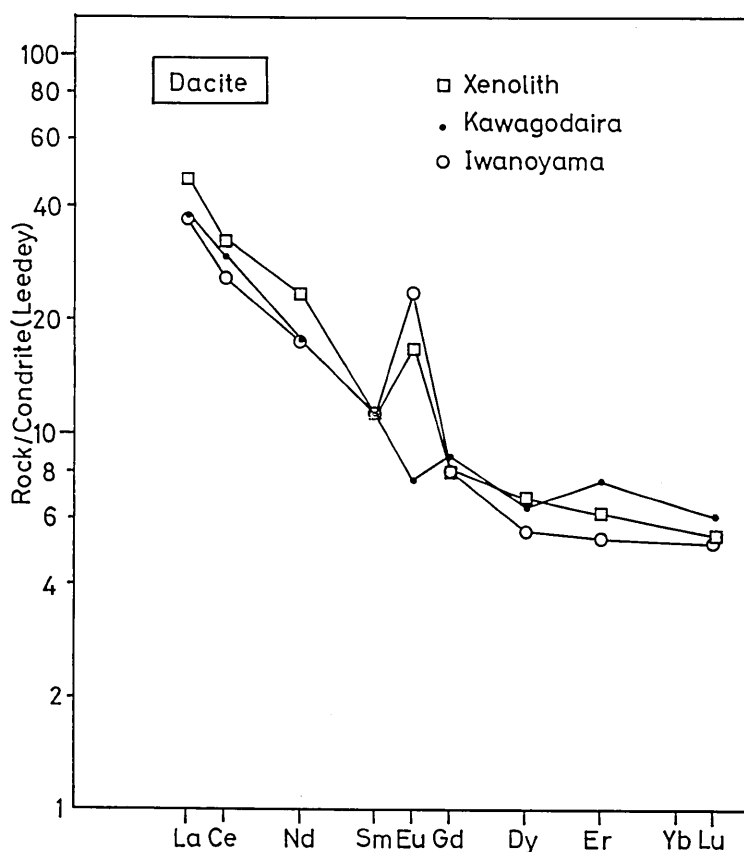


Fig. 13(C)

Fig. 13. Chondrite-normalized rare-earth element patterns for the rocks of the Higashi-Izu monogenetic volcano group. (A): basalts (Joboshi (KH-16), Inatori-1 (KH-42)), (B): andesites (Omuroyama (KH-18), Dainoyama (KH-8)), (C): dacites (Kawagodaira (KH-37), Iwanoyama (KH-12)) and granitic xenolith collected from Iwanokubo deposits.

Kawagodaira) and granitic xenolith collected from Iwanokubo deposit are similar, but the slopes are steeper than those of basalts and andesites. Though the Iwanoyama and the Iwanokubo xenolith have a positive Eu anomaly, Kawagodaira generally shows a negative Eu anomaly.

The following procedure follows that described by FUJIMAKI (1977). The La and Lu contents normalized against the contents in Joboshi basalt are plotted in Fig. 14. Slopes of the lines indicated as the fractionation trend of minerals are obtained from the ratios of the partition coefficient of La that of Lu for individual minerals. If a point representing the composition of a magma is located within the

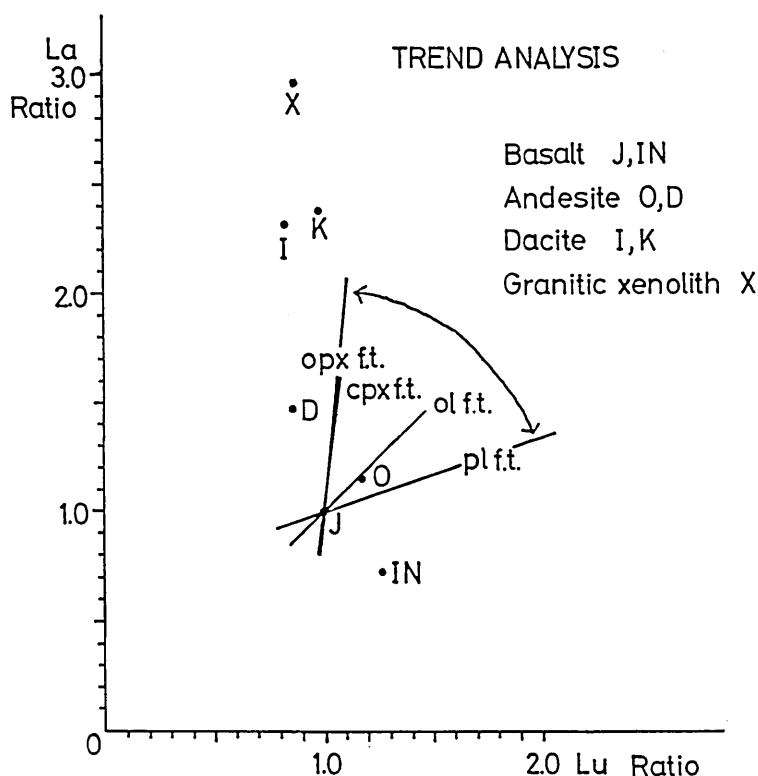


Fig. 14. Rare-earth elements trend analysis on the rocks of the Higashi-Izu monogenetic volcano group. f.t.: fractionation trend, J: Joboshi, IN: Inatori-1, O: Omuroyama, D: Dainoyama, I: Iwanokubo, K: Kawagodaira, X: granitic xenolith collected from Iwanokubo deposits. Vertical and horizontal axes are the ratios of La and Lu contents of the rocks to those of Joboshi basalt.

area indicated by an arrow, that magma (indicated by the point) can be derived from that of Joboshi through the crystallization differentiation. If the point is out of the area, the magma cannot be derived from that of Joboshi by the simple crystallization differentiation.

As is seen from Fig. 14, the magma of Inatori 1 (Basalt II) cannot be derived from that of Joboshi (Basalt I) only by the crystallization differentiation and vice versa as far as the REE contents are concerned. Omuroyama andesite (Andesite I) can be derived from that of Joboshi by the crystallization differentiation. Dainoyama andesite (Andesite III) cannot be derived from the basaltic liquids of Joboshi and Inatori 1 by the crystallization differentiation. The rocks of Omuroyama always contain xenocrysts derived from the granitic rocks. The result of addition-subtraction calculation of the compositions of Omuroyama, Joboshi and the granitic xenolith according to FUJIMAKI (1977) is listed in Table 6. The calculation is divided into two steps;

Table 6. Rare-earth element data of the rocks of the Higashi-Izu monogenetic volcano group.

	1	2	3	4	5	6	7
La	6.05	4.45	6.96	8.91	14.04	14.42	17.84
Ce	14.98	12.44	17.63	22.52	24.96	28.51	31.55
Nd	10.18	9.06	11.68	13.93	12.51	12.74	16.72
Sm	2.76	2.52	3.18	3.00	2.64	2.57	2.55
Eu	1.370	0.8722	1.055	0.970	2.048	0.658	1.4547
Gd	3.22	3.13	3.41	3.23	2.50	2.71	2.49
Dy	3.09	3.49	3.18	2.60	2.17	2.55	2.65
Er	1.79	2.23	1.93	1.35	1.36	1.65	1.59
Yb	1.61	1.99	1.86	1.39	n.d.	n.d.	n.d.
Lu	0.241	0.307	0.284	0.208	0.202	0.238	0.211
(ppm)	analyzed by H. FUJIMAKI						

1: basalt (Joboshi, KH-16, No. 9 in Table 4)

2: basalt (Inatori 1, KH-42, No. 29)

3: andesite (Omuroyama, KH-18, No. 45)

4: andesite (Dainoyama, KH-8, No. 56)

5: dacite (Iwanoyama, KH-11, No. 59)

6: dacite (Kawagodaira, KH-37, No. 58)

7: granitic xenolith (Iwanokubo, No. 63)

Table 7. Method of calculation of REE fitting.

(A) Addition-Subtraction Calculation

	KH-16	O180	P185	XENO			KH-18	Cal.
SiO ₂	50.29	39.13	46.40	74.50	0.00	0.00	*55.79	55.77
TiO ₂	0.99	0.02	0.03	0.26	0.00	0.00	* 0.86	0.91
Al ₂ O ₃	18.16	0.00	33.59	13.43	0.00	0.00	*17.13	17.23
FeO*	9.23	18.28	0.63	1.83	0.00	0.00	* 7.67	7.77
MnO	0.17	0.29	0.00	0.05	0.00	0.00	* 0.15	0.15
MgO	7.79	42.10	0.10	0.56	0.00	0.00	* 5.58	5.56
CaO	10.10	0.17	17.73	2.25	0.00	0.00	* 8.70	8.55
Na ₂ O	2.47	0.01	1.64	4.04	0.00	0.00	* 3.07	2.90
K ₂ O	0.40	0.00	0.03	3.04	0.00	0.00	* 0.76	0.96
P ₂ O ₅	0.39	0.00	0.00	0.04	0.00	0.00	* 0.27	0.35

Ratio 0.8654 - .0307 - .0359 0.2030 0.0000 0.0000 Sum of Squares of Oxide

Residuals .118293

(B) Method of calculation

Step 1 Subtraction of olivine and plagioclase

KH-16 100%

O180 -3.547%

P185 -4.148%

Step 2 Mixing of the liquid obtained in Step 1 and granitic xenolith

Liquid 79.74%

Xenolith 20.26%

(Result)

La	Nd	Sm	Gd	Er	Lu
8.84	12.20	2.95	3.30	1.88	0.254 (ppm)

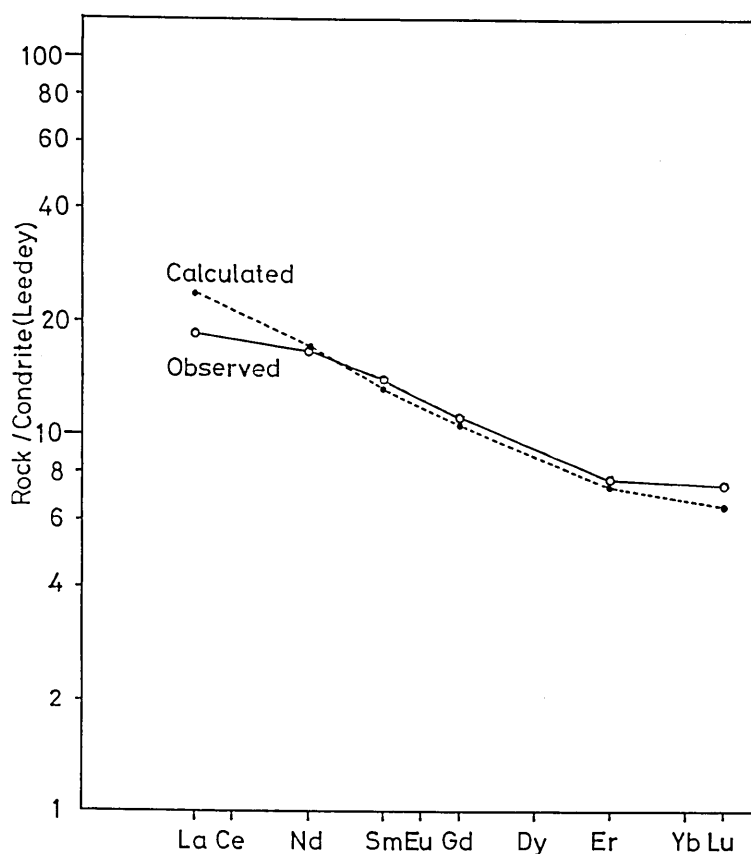


Fig. 15. Chondrite-normalized pattern of the rocks of Omuroyama and the calculated chondrite-normalized pattern by the contamination of the basalt (Joboshi (KH-16)) with the granitic rock collected from Iwanokubo deposit.

Rayleigh fractionation calculation and simple mixing calculation of the liquid and the granitic xenolith. The result of calculation is shown in Table 7 while the calculated and observed patterns are plotted in Fig. 15. Except for La, the contents of the other elements are almost the same. This supports the idea that the magma of Omuroyama was produced by the contamination of the basaltic magma with the granitic rocks. The difference of the REE patterns, a higher content of the light REE in dacite than those in basalt-andesite, denies the crystallization of the basaltic magma for the origin of dacite magmas.

The Ni and Cr contents of the rocks from this volcano group (analyzed by H. HARAMURA) are listed in Table 4. Cr may mostly be confined in chromian spinel (picotite) enclosed within olivine crystals and Ni may mostly be contained in olivine. Thus the separation of olivine and chromian spinel decreases the Ni and Cr contents of the

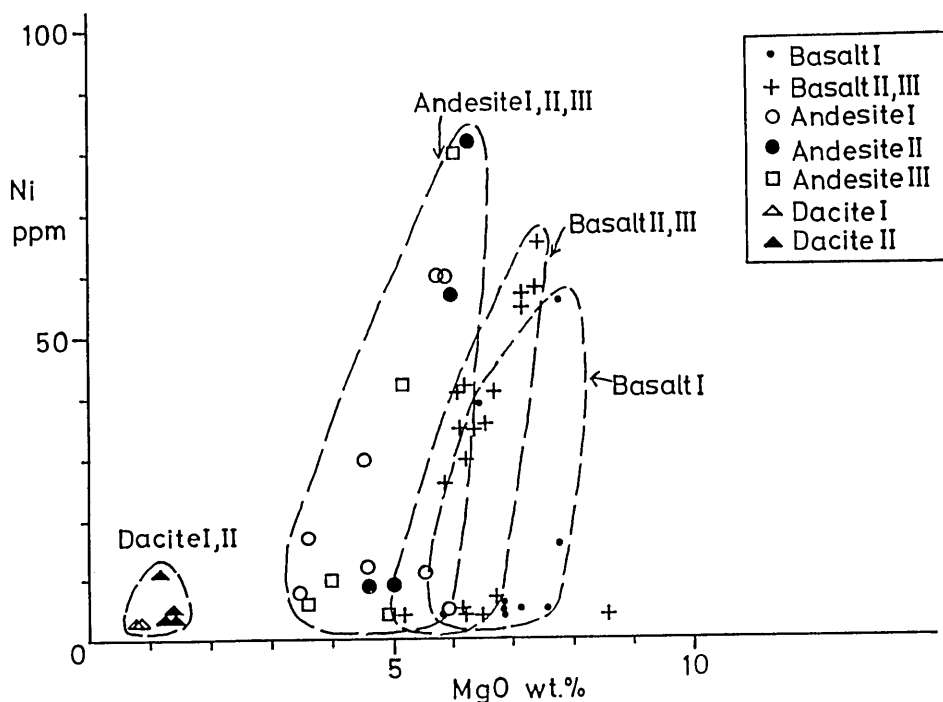


Fig. 16(A)

magma effectively. However, two rocks from Sukumoyama collected at the same locality (KH-13A, B) show a difference in Cr content even though they have a similar composition of major elements. A similar phenomenon occurs in the Cr content of the rocks from Joboshi (KH-16A, B). As picotite crystals are very tiny and the Ni content in olivine crystal decreases rapidly from core to rim, the heterogeneous distribution of picotite crystal and the patches with higher Ni concentration found in olivine crystals may have caused these differences.

The Ni and Cr contents are plotted against the MgO content in Figs. 16A and B. Dots and crosses indicate the rocks of Basalt I and those of Basalt II and III respectively. The rocks of Basalt II and III have a higher Ni content than those of Basalt I with the same MgO value. The trend observed in the respective broken lines may correspond to the separation of olivine and chromian spinel. The shift of distribution for Andesites (open circles) may be explained by the contamination of granitic rocks. Dacite II (Iwanoyama, Yahazuyama and Ananoyama) which includes magnesian olivine, Ca-rich clinopyroxene and Ca-rich plagioclase xenocrysts shows a slightly higher Cr and Ni content than those of Dacite I (Kawagodaira) which is free of

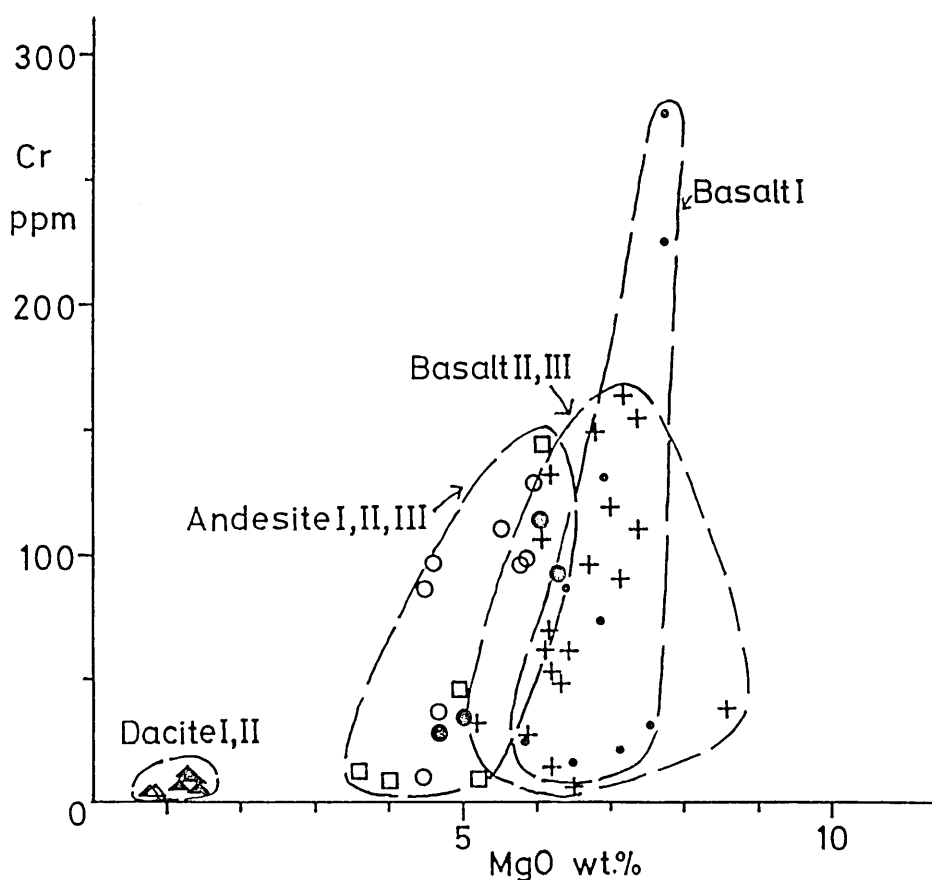


Fig. 16(B)

Fig. 16. Plots of MgO versus Ni (A) and MgO versus Cr (B) of the rocks of the Higashi-Izu monogenetic volcano group.

xenocrysts.

IV. Spatial variations

Spatial variations of several characters in this volcano group and the part of the Higashi-Izu-oki submarine volcano group that has similar chemical and mineralogical characteristics to this volcano group (HAMURO *et al.*, 1980, 1983) are shown in Figs. 17A-E.

The spatial variation of phenocryst assemblages of the rocks from this volcano group and these from the Higashi-Izu-oki submarine volcano group is presented in Fig. 17A. Basalt I and Andesite I having olivine+plagioclase phenocryst assemblage are mostly confined to area A encircled by the broken line. Basalt II and Andesite II having an

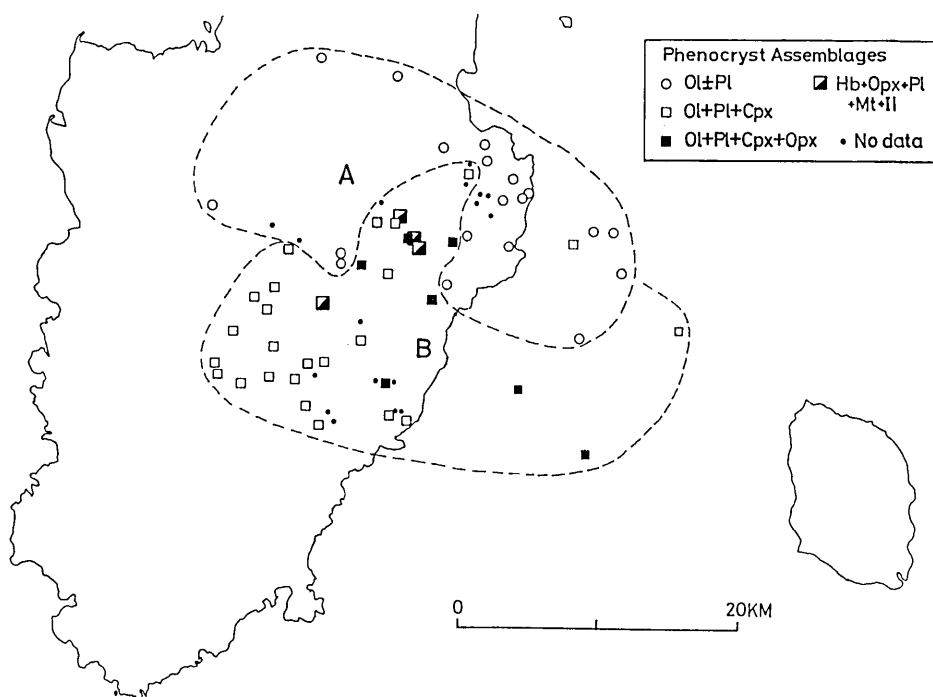


Fig. 17A. Regional distribution of the phenocryst assemblages in the rocks of the Higashi-Izu monogenetic volcano group.

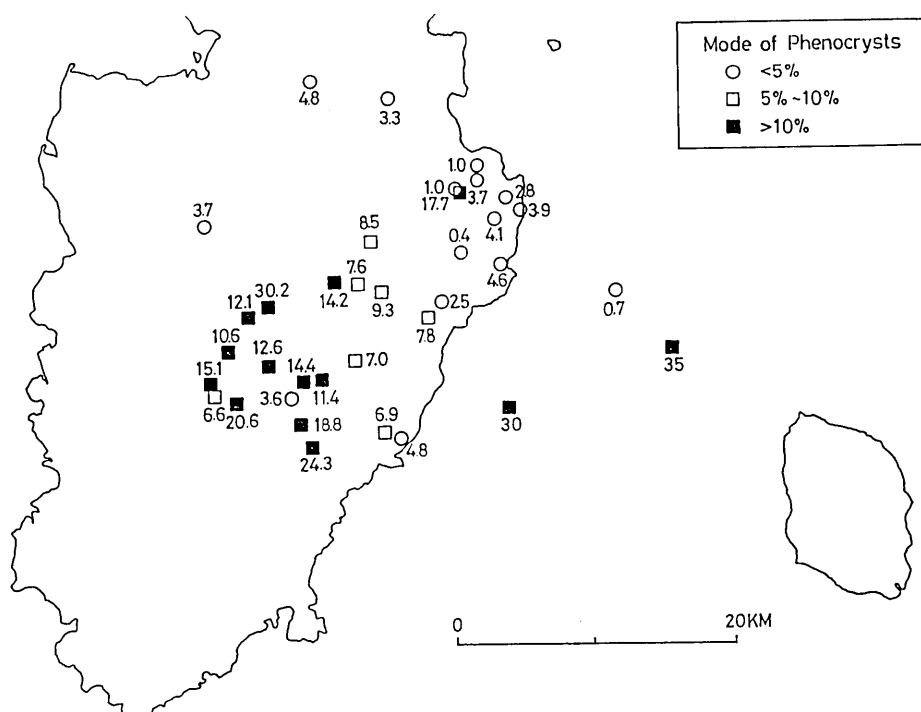


Fig. 17B. Regional distribution of mode of phenocrysts in the rocks of the Higashi-Izu monogenetic volcano group.

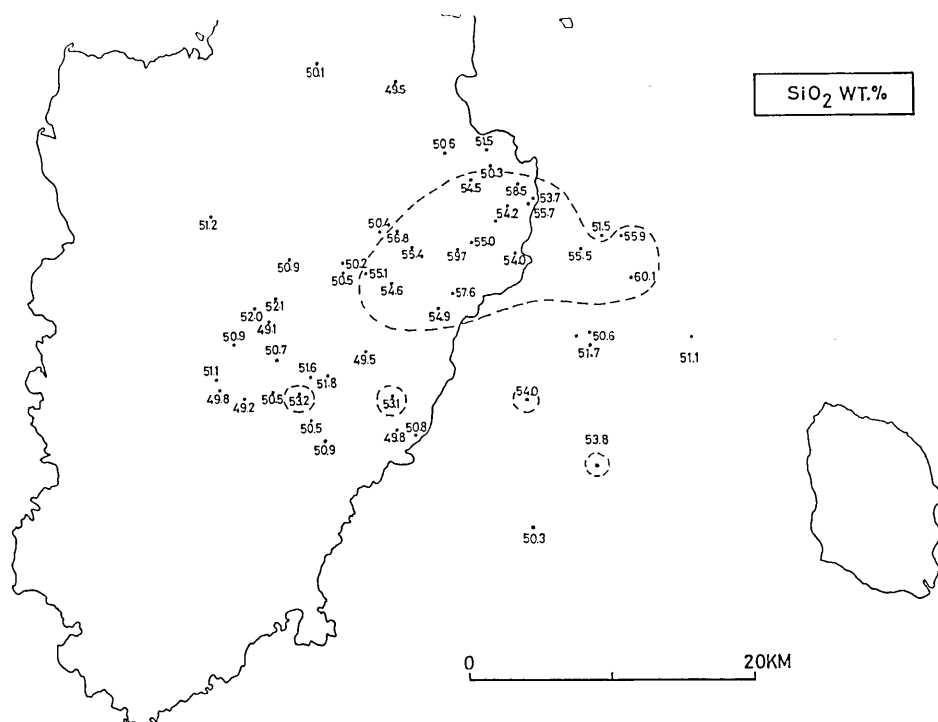


Fig. 17C. Regional distribution of SiO₂ content in the rocks of the Higashi-Izu monogenetic volcano group. The rocks with a SiO₂ content of more than 53 wt. % are distributed in the areas enclosed by dotted lines.

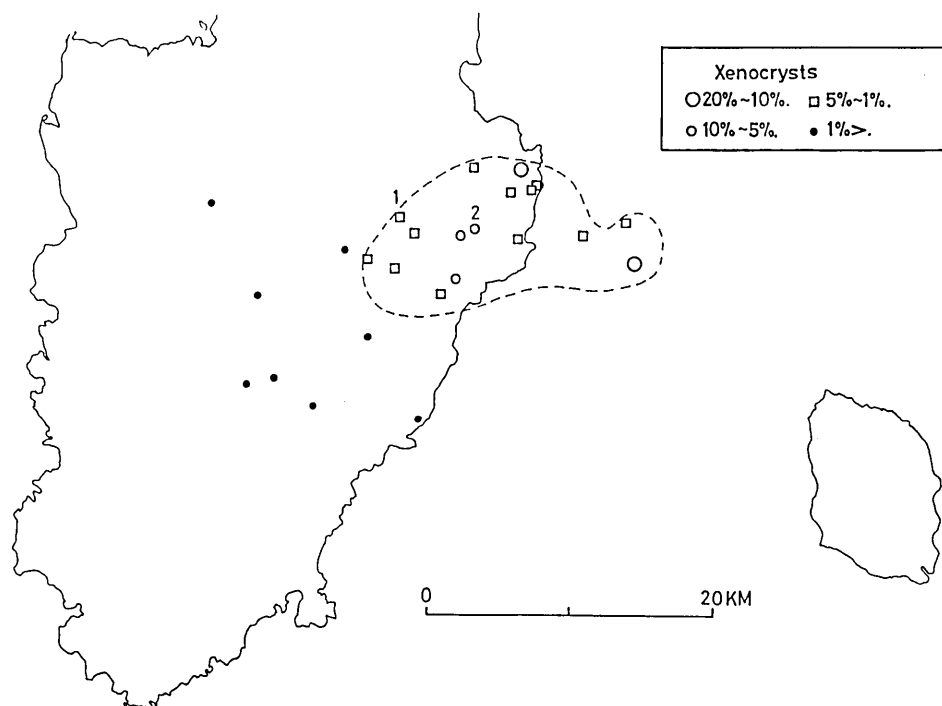


Fig. 17D. Regional distribution of the rocks with granitic xenocrysts of the Higashi-Izu monogenetic volcano group.

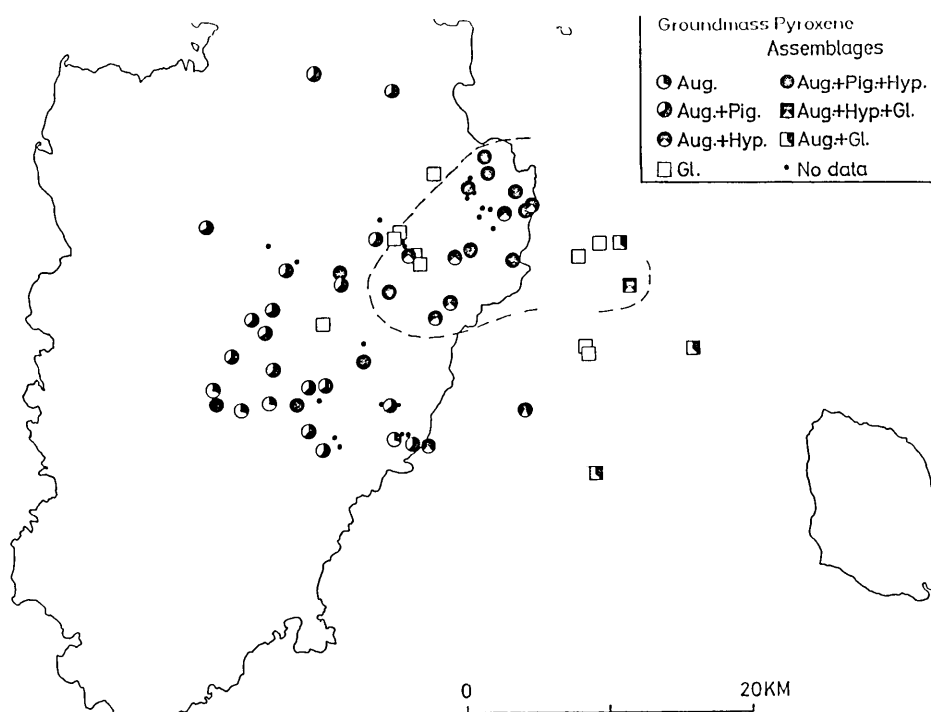


Fig. 17E. Regional distribution of the groundmass in the rocks of the Higashi-Izu monogenetic volcano group.

olivine+plagioclase+clinopyroxene assemblage occur in area B and Basalt III and Andesite III having an olivine+plagioclase+clinopyroxene+orthopyroxene phenocryst assemblage are concentrated in the eastern part of area B. This variation corresponds to the Na_2O content of the rocks in area B being generally higher than that in area A, as described in the preceding section (Fig. 9). The dacites are distributed almost in the center of the volcano group, especially in area B. Modal volume of phenocrysts in most of Basalt I and II is shown in Fig. 17B. This figure indicates that most of Basalt II have a higher modal volume than Basalt I, although there are some exceptions such as Inatori 1, Amagi Highland-higashi and Marunoyama.

The spatial variation of the SiO_2 contents of basaltic and andesitic rocks is shown in Fig. 17C. The areas encircled by the broken lines contain the rocks with a SiO_2 content of more than 53 wt.%. Most of these rocks occur in the northeastern part of this volcano group.

The distribution of the basaltic and andesitic rocks contained xenocrysts and their modal volume is shown in Fig. 17D. The rocks which contain xenocrysts of more than 1% in modal volume are distributed

within the area enclosed by the broken line. Several basalts outside this area also rarely contain xenocrysts, but their amount is quite insignificant. Nos. 1 and 2 correspond to vent localities from where granitic materials were collected (KUNO, 1954; this study). This distribution strongly indicates that substantial contamination with granitic materials has taken place only within the area, the rocks outside the area being almost free of contamination.

The distribution of the groundmass pyroxene assemblages is shown in Fig. 17E. The rocks with hypersthene in the groundmass are mostly concentrated in the area enclosed by the broken line and only five with such groundmass are found outside the area.

The areas enclosed by the broken lines observed in Figs. 17C, D and E are almost identical. This similarity strongly suggests the close correlation among the contamination by granitic materials, the SiO_2 enrichment, and the groundmass pyroxene assemblage. This area is located mainly in area A and partly in area B in Fig. 17A.

V. Melting experiments

After pulverizing a rock sample by a tungsten-carbide ball mill for 40 minutes, the powder is ground in an agate mortar using ethyl alcohol as a retaining agent. The alcohol is evaporated and the sample is completely dried in an oven. The powder is compressed to make a disk using an aluminum ring. The compressed disk is broken into pieces (about 4 mm in diameter and 100–50 mg in weight). One of these pieces is wound by a platinum wire 0.05 mm in diameter similar to that described by DONALDSON, WILLIAMS and LOFGREN (1975). The sample is melted in a furnace at $f_{\text{O}_2} = 10^{-8}$ atm and 1300°C for 15 minutes and then quenched to make a glass bead. This glass bead with a short platinum wire is used as the starting material in the experiments.

The oxygen partial pressure in the gas is controlled by passing mixtures of H_2 and CO_2 upward through the furnace tube past the sample at a rate of 8 cc per second. A gas mixer like that described by DARKEN and GURRY (1945) is used to obtain a mixed gas of a described composition. The values of oxygen partial pressure computed by the method described by DARKEN and GURRY (1945) are adopted. The furnace used in the experiments is a vertical type Pt-Rh resistance quenching furnaces. The temperature is controlled by an electronic controller (Okura Electric EC 51/2).

A thermocouple is inserted into the center of the furnace for adjusting to a desired temperature. The overall temperature control

Table 8. Experimental results of Sukumoyama and Joboshi samples.

	T(°C)	$-\log f_{O_2}$	Phases
Sukumoyama			
	1220	8	pl
	1200	3.9	pl+ol+sp
	1200	8	pl+ol
	1190	8	pl+ol
	1180	4.0	pl+ol+sp
	1180	8	pl+ol
	1180	10	pl+ol
	1170	8	pl+ol+sp
	1160	4.1	pl+ol+sp
	1160	10	pl+ol
	1150	4.1	pl+ol+sp+cpx
	1150	8	pl+ol+sp+cpx
	1150	10	pl+ol+cpx
	1140	10	pl+ol+cpx
	1130	4.2	pl+ol+sp+cpx
	1130	8	pl+ol+sp+cpx
	1120	8	pl+ol+sp+cpx
Joboshi			
	1230	8	pl
	1220	8	pl
	1210	8	pl
	1200	8	pl+sp
	1190	8	pl+sp+ol
	1180	8	pl+sp+ol
	1170	8	pl+sp+ol
	1160	8	pl+sp+ol
	1150	8	pl+sp+ol
	1140	8	pl+sp+ol
	1130	8	pl+sp+ol+cpx

pl; plagioclase, ol; olivine, sp; spinel, cpx; clinopyroxene.

is kept precisely within $\pm 2^\circ\text{C}$.

Nearly aphyric rocks of olivine and plagioclase phenocryst assemblage that represent the liquid on the cotectic boundary between olivine and plagioclase fields are used in the experiments. The petrographic descriptions are given in the preceding section. The run products are mounted on thin sections for phase identification under the microscope. The experimental results are listed in Table 8 and are shown in Fig. 18.

The spinel crystallization temperature for the Sukumoyama sample decreases rapidly with lowering in the oxygen partial pressure. At $P_{O_2}=10^{-8}$ atm the crystallization temperature of the spinel phase is about 30°C lower than that of olivine in Sukumoyama basalt but 10°C higher than that in Joboshi basalt. This is due to the difference in chromium content in the sample. Chromium stabilizes the spinel

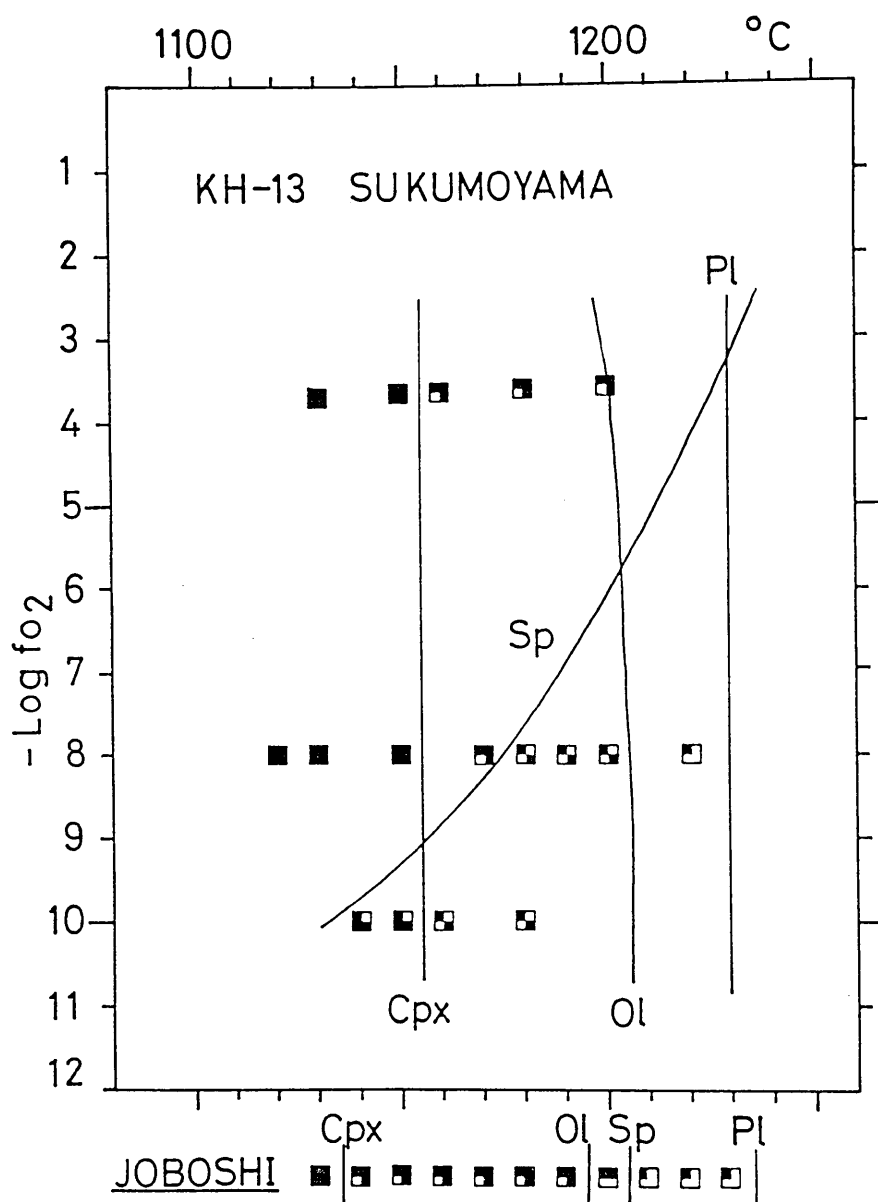


Fig. 18. $-\log f_{O_2}$ versus temperature, showing liquid curves and phase assemblage field for Sukumoyama (KH-13) and Joboshi (KH-16) samples. A: plagioclase, A: olivine, A: clinopyroxene, A: spinel.

phase at a higher temperature at relatively low oxygen partial pressure (HILL and ROEDER, 1974). The Chromium contents of samples from Sukumoyama and Joboshi are 31 ppm and 277 ppm respectively.

The oxygen partial pressure in the natural basaltic magma is es-

estimated to be about 10^{-8} atom (FUDARI, 1965; SATO and WRIGHT, 1966; SHIBATA, 1967). The discussion will be limited to the result at 10^{-8} atom. The samples used in the experiments are nearly aphyric basalts with a little olivine and plagioclase phenocrysts. Both crystals are also observed as constituents in the groundmass. These samples represent the liquid compositions in equilibrium with olivine and plagioclase crystals just before the magmas extrude to the surface. The experimentally determined liquidus temperature of plagioclase is appreciably higher than that of olivine. The experiment done on an aphyric Warner basalt that is classified as the high-alumina basalt by KUNO (1960) also shows similar results, that is, the first crystallizing phase is plagioclase, even the MgO content is about 10 wt.% (HAMURO, unpublished data). This does not explain the phase relation actually observed in the rocks. This result suggests the existence of some effect that lowers the liquidus temperature of plagioclase, probably the effect of water. At depths in the crust the H_2O contained in the magma effects to lower the crystallization temperature of crystals. This effect is more pronounced in plagioclase than in olivine (YODER and TILLEY, 1962). Similar conclusion was reached by several workers (YODER and TILLEY, 1962; BROWN and SCHAIRER, 1971). Probably the existence of an unknown amount of water in magma is a common character in the high-alumina basalt magma. Anhydrous melting experiments on abyssal tholeiite (FUKUYAMA and HAMURO, 1977) explain the phase relation actually observed in the rocks. They concluded that the abyssal tholeiite magma crystallized under a nearly anhydrous condition. The difference of results in these anhydrous atmospheric melting experiments mainly depends on the difference of the Al_2O_3 contents in the rocks; the higher the Al_2O_3 content, the higher the crystallization temperature of plagioclase.

VI. Discussion

(a) Formation and Crystallization of basaltic magma

In this report basalt is classified as the rocks with a SiO_2 content between 49 and 53 wt.%. Sporadic xenocrysts probably inherited from granitic rocks are observed in several rock samples (Fig. 17D). As the quantity is negligibly small, the basalts are regarded as free from contamination by granitic rocks. Although three phenocrystic assemblages are observed in the basalts; $Ol \pm Pl$ (Basalt I), $Ol + Pl + Cpx$ (Basalt II) and $Ol + Pl + Cpx + Opx$ (Basalt III), the first and the second assemblages are prominent.

Basalt I generally shows higher contents of MgO and FeO^* and

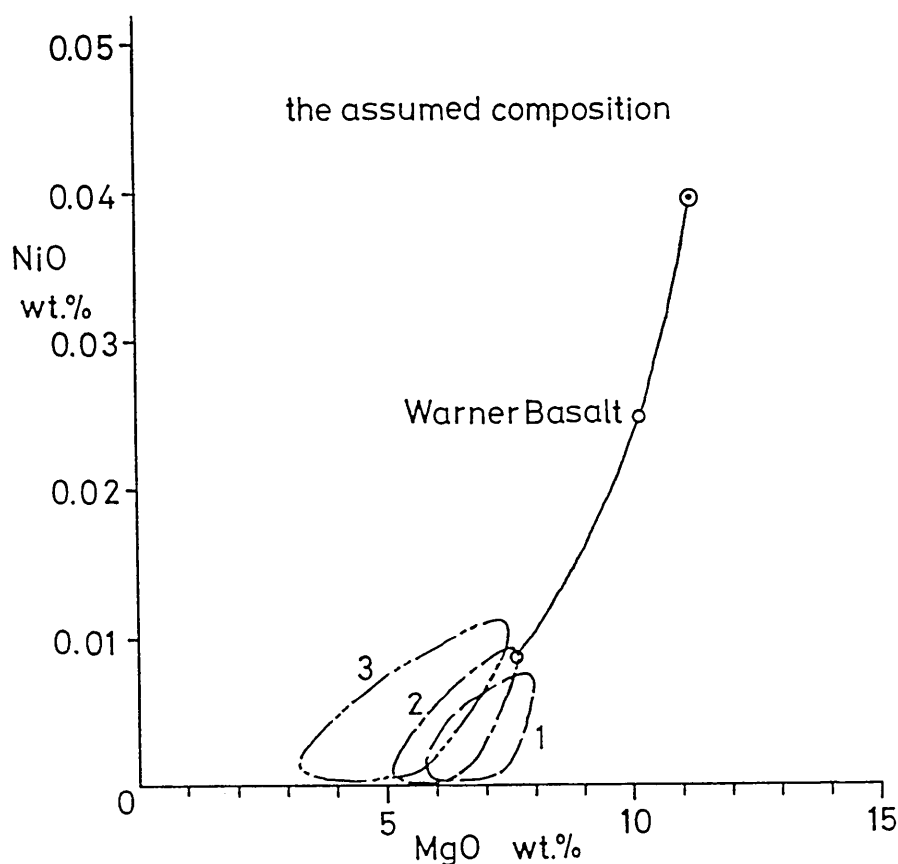


Fig. 19. MgO versus NiO plot of the basaltic rocks of the Higashi-Izu monogenetic volcano group. 1: Basalt I, 2: Basalt II, 3: Andesite. Open circles indicate Warner basalt (MERTZMAN, 1977).

lower contents of Na_2O and CaO than those of Basalt II. However, some of Basalt II (Inatori 1, Amagi Highland-higashi and Marunoyama) show a similar Na_2O content to Basalt I rather than Basalt II. The addition-subtraction calculation shows that such Basalt II can be derived from Basalt I, although the calculations for other Basalt II match up poorly. Basalts of Inatori 1 and Amagi Highland-higashi can be derived by subtracting a small amount of olivine and plagioclase and adding clinopyroxene with more than 10 wt.% while Marunoyama can be derived by subtracting olivine and plagioclase. The REE patterns of Joboshi (Basalt I) and Inatori 1 (Basalt II) suggest that neither of the two magmas can be derived from the other though the crystallization differentiation of olivine, plagioclase and clinopyroxene. Based on the Sr/Ca Ba/Ca ratios HIRANO *et al.* (1982) suggested that

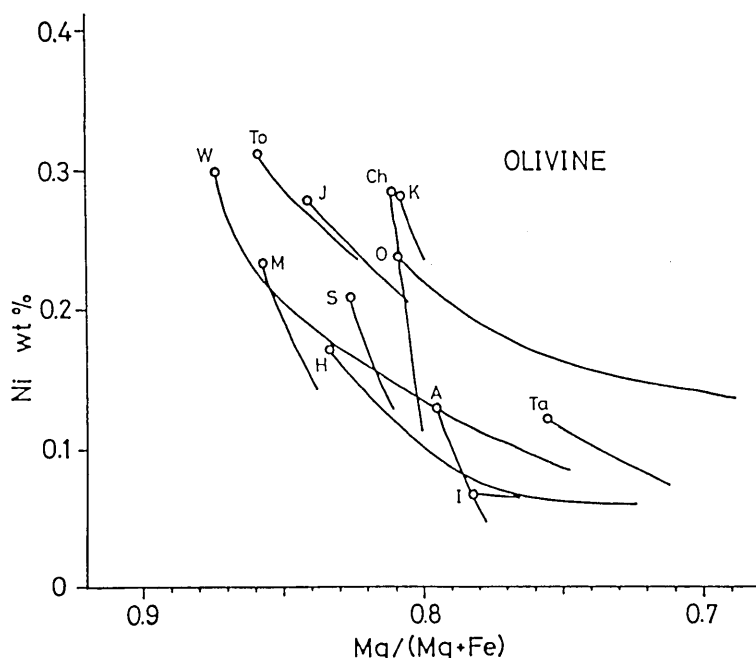


Fig. 20. NiO contents in olivine phenocrysts in the rocks of the Higashi-Izu monogenetic volcano group. The length of each curve represents the whole range in composition of the phenocrystic olivine crystals contained in a single rock. To: Togasayama (KH-49), J: Joboshi (KH-16), M: Marunoyama (KH-6), S: Sukumoyama (KH-13), H: Hachiyama (KH-39), Ch: Chikubo (KH-20), K: Komuroyama (KH-19), O: Omuroyama (KH-18), A: Ananoyama (KH-50), I: Iwanoyama (KH-11), Ta: Takatsukayama (KH-38). Open circles indicate the most magnesian olivine in each rock sample (W: Warner basalt (KUNO's sample)).

these basalts (Basalt II) are remelts of a cumulus phase (or gabbroic rocks) left over by the generation of Basalt I magma type or mixtures of the cumulus phase and Basalt I type magma. Although the rocks of Basalt II are mainly distributed in the southeastern part of this volcano group, samples collected from one of volcanoes in the Higashi-Izu-oki submarine volcano group show the same characteristics in phenocryst assemblage and chemical composition. So it is difficult to say that the Na_2O contents of the rocks become greater toward the west. According to these data, Basalt I and II are closely related, but some involvement of other materials such as those suggested by HIRANO *et al.* (1982) might be needed to produce Basalt II.

The MgO versus NiO relation of the basalts from this volcano group and the Warner basalt of the northeastern part of California is shown in Fig. 19. The trace of assumed liquid equilibrated with the mantle peridotite suggested by SATO (1977) is drawn in the figure.

During the process of fractional crystallization differentiation, the NiO content in olivine crystallizing from the liquid decreases as that in the liquid does. Although the groundmass olivine or rim of olivine phenocryst is equilibrated with the groundmass liquid, the core of olivine phenocrysts corresponds to that in the earlier stage of crystallization. The most magnesian olivine contained in the rocks indicates the less differentiated liquid. The NiO content in olivine contained in the rocks from this volcano group is shown in Fig. 20. The length of each represents the whole range in composition of phenocrystic olivine crystals contained in a single rock sample. The highest NiO value in olivine is 0.31 wt.%. A Warner basalt described by ANDERSON (1941) is a high-alumina basalt similar to the basalts in this volcano group. The most mafic rock of the Warner basalt that has 10.13 wt.% (KUNO's sample, newly analyzed in this study) and its differentiate that has 7.49 wt.% of MgO (MERTZMAN, 1977) contain 197 ppm and 71 ppm of Ni respectively. Warner basalt of the latter corresponds to the most magnesian basalts from this volcano group (basalt I), i.e., Sukumoyama and Joboshi. The NiO content in olivine is 0.31 wt.% for the most mafic Warner basalt (KUNO's sample). A comparison of the NiO content in olivine indicates that this olivine had been equilibrated with more magnesian liquid than these rocks have at present, at least 10 wt.% of MgO, probably more. FUKUYAMA (1978), based on his study of Ni contents of the volcanic rocks and their olivine phenocrysts, showed that the volcanic rocks from Quaternary volcanoes in Japan had already been differentiated and did not hold their original composition. As discussed above, the Ni contents of the basaltic rocks from this volcano group strongly suggest that these rocks are in advanced stages of crystallization differentiation and do not hold their original composition. TATSUMI *et al.* (1982) estimated that about 13% of olivine crystals had been subtracted from the primitive magma to form the basalts of this volcano group. HIRANO *et al.* (1982) also pointed out that Basalt I is considered to represent evolved liquid composition through olivine crystallization based on the Sr/Ca and Ba/Ca ratios.

These basalts are classified as the high-alumina basalt as defined by KUNO (1960). Though these basalts are differentiated, the higher Al_2O_3 content of this rock type even in aphyric rocks than in other basalts, i.e., plateau basalts, abyssal tholeiites, low-alkali tholeiites and oceanic island tholeiites, may have been present in the primitive stage of the magma, because the relative abundance of Al_2O_3 content in liquids crystallizing olivine does not change.

The result of anhydrous melting experiments and other referred experiments indicates the existence of an unknown amount of water

in magma may be a common character of the "high-alumina basalt magma". There is a possibility that the primitive liquid of these basalts (Basalt I) containing a certain amount of water had been equilibrated with the mantle peridotite in the uppermost mantle under the Izu Peninsula.

(b) Formation of andesites by contamination

The andesite is here classified as the rocks with a SiO_2 content of more than 53 wt.% and less than 60 wt.%. These rocks are distributed in the northeastern part of this volcano group as shown in Fig. 17. Three phenocryst assemblages are observed in andesites; Ol+Pl, Ol+Pl+Cpx, and Ol+Pl+Cpx+Opx. Most of the andesites have an Ol+Pl phenocryst assemblage. These rocks always contain granitic xenocrysts (quartz, plagioclase, hornblende (or biotite), and opaques), suggesting the contamination of the basaltic magma with granitic rocks. The positive correlation between the mode of xenocrysts and the SiO_2 content of andesites shown in Fig. 12 also indicates the contamination. The slight difference in the $\text{Sr}^{87}/\text{Sr}^{86}$ ratios in andesites with a different amount of xenocrysts from Komuroyama (KURASAWA, 1979) may also suggest the contamination of the granitic rock, although that ratio in the granitic rock is not measured. The granitic xenoliths containing the same minerals as xenocrysts are found in lava flows and scoria deposits. The contamination of the basaltic magma with the granitic rock is also demonstrated by the addition-subtraction calculation of major elements and the rare earth elements as discussed in the preceding section. Thus most of the andesites from this volcano group are interpreted to have been produced mainly by the contamination of the basaltic magma, mostly the Basalt I type with the granitic rocks in the crust. The rest of the andesites may be produced also by contamination of either Basalt II or III with the granitic rock. However, there is a possibility of magma mixing as the origin of some andesites, e.g. Iwanokubo and Ananokubo, which are closely related in location and age to the dacitic lava domes with basaltic xenocrysts.

The groundmass pyroxene assemblages of basalts in this volcano group are augite, augite+pigeonite and augite+pigeonite+hypersthene. Those of andesites are augite+pigeonite+hypersthene and augite+hypersthene. According to the definition of the rock series proposed by KUNO (1950) using the groundmass pyroxene assemblages, most of Basalt I and II are classified as the "pigeonitic rock series" (only clinopyroxenes in the groundmass) and some basalts such as Joboshi, Uchino, and andesites are classified as the "hypersthene rock series" (orthopyroxene+augite \pm pigeonite). The change from assemblages with

or without groundmass hypersthene in basalts to those with groundmass hypersthene in andesites may depend on the change of the liquid composition caused by the contamination of granitic rocks.

(c) Formation of dacites by remelting of the crust

Two ways are suggested as the origin of dacites (SiO_2 higher than 68 wt.%); namely the crystallization differentiation of the basaltic magma and the melting of the granitic crust.

Paucity of the intermediate composition between andesites and dacites of this volcano group does not favor the crystallization differentiation of the basaltic magma. The difference of the REE patterns, a higher content of the light REE in dacite than in basalt-andesite, denies the crystallization differentiation of the basaltic magma as the origin of dacitic magma (FUJIMAKI, 1977).

The contents of the major elements and the REE of the dacites are almost the same as the granitic rock found as xenoliths in this area. The close occurrence of the basic and acidic magmas in time and place are observed in this volcano group (HAMURO, 1978). The Iwanoyama-Ananoyama-Yahazuyama lava domes and the Iwanokubo crater. The basic magma erupted from Iwanokubo crater carried the partially melted granitic xenolith and xenocrysts. The dacites constituting domes contain xenocrysts probably belonging to basaltic rocks or magma (olivine, plagioclase, and clinopyroxene, rarely basaltic inclusions). These facts also suggest the possibility of a partial melting of the granitic rocks by the basaltic magma for the origin of the dacitic magma consisting of liquid and relict minerals (Dacite I). Chemical variations within three dacitic lava domes (Dacite II) are explained by the assimilation of the basaltic rock or basaltic magma. The dacites contain plagioclase crystals with a zone of discontinuity in zonal structure that is an indication of resorption and subsequent overgrowth similar to that described by OSHIMA (1975). They also contain resorbed quartz crystals. These are observed in the rocks of Kawagodaira and three domes which erupted in different times and places. Although these minerals may be the resorbed phenocrysts crystallizing from the dacite magma for the change of the conditions, for instance the $\text{P}_{\text{H}_2\text{O}}$ change, there is a possibility of the relict minerals remelting.

(d) Comparison with other monogenetic volcano groups

The monogenetic volcano group consists mainly of many monogenetic volcanoes that were built by a single eruptive cycle; i.e., maar, scoria cone, pumice cone, lava dome, lava flow, and so on. Monogenetic volcanoes also occur as parasitic volcanoes of a main

volcano (stratovolcano and shield volcano), such as those of the Fuji and Oshima volcanos. However, these are not classified as the monogenetic volcano group in this study.

Based on this classification, monogenetic volcano groups in the Quaternary age studied well are picked up from literature; The Three Sisters region (WILLIAMS, 1944; TAYLOR, 1968), Modoc region (FINCH and ANDERSON, 1930; POWERS, 1932; ANDERSON, 1933; FINCH, 1934; CONDIE and HAYSLIP, 1975), and Clear Lake region (ANDERSON, 1936) in the U.S.A., Paricutin region (WILLIAMS, 1950; WILCOX, 1954) and Mexico City region (MOOSER *et al.*, 1974; BLOOMFIELD, 1975) in Mexico and the Southeastern Guatemala region in Guatemala (WILLIAMS, MCBIRNEY and DENG, 1964).

The activity of a monogenetic volcano ceases within a relatively short time from a few hours to several years. The active period of the monogenetic volcano group as a whole is estimated at a few tens of thousand years; i.e. Higashi-Izu monogenetic volcano group from (about 30,000 to about 3,000 years ago). The Three Sisters region (from over 10,000 years ago to the present), the Clear Lake region (from an unknown period to a few thousand years ago), the Paricutin region (from an unknown period, the Paricutin volcano was active for ten years from 1943 to 1952), the Mexico City region (about 40,000 years ago to about 8,000 years ago) and the Southeastern Guatemala region (from an unknown period to a few thousand years ago).

There are two types of the monogenetic volcano groups based on the erupted magmas. One is the unimodal type that is composed of basic magma, the other is the bimodal type that is composed of the basic and acidic magmas. The former is observed in the Paricutin and Mexico City regions, and the latter is observed in the Higashi-Izu monogenetic volcano group, the Three Sisters, Modoc, Clear Lake and Southeastern Guatemala regions. The acidic magma activity in the bimodal type occurred at a relatively younger age in their history of activity. In some cases both magmas erupted within a short period and in close localities such as in this volcano group and in Southeastern Guatemala (WILLIAMS, MCBIRNEY and DENG, 1964).

A part of the erupted materials in the basic member of both type mostly contain xenocrysts of quartz and plagioclase and xenoliths of basic member and basic inclusions derived from the basic magma or the crustal materials during the magma ascent to the surface, i.e. this volcano group, Modoc, Three Sisters and Clear Lake.

These xenocrysts and xenoliths in both members suggest the existence of interaction of magma with the crust or with a different kind of magma.

The magmas erupted in the monogenetic volcano groups listed above mostly belong to high-alumina basalt and alkali basalt series. The rocks of the low-alkali tholeiite are not found in the monogenetic volcano groups. This might be simply because the occurrence of the rocks of the low-alkali tholeiite is more restricted than in the other two series.

Acknowledgements

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東伊豆単成火山群は、伊豆半島北部に位置し、350 km² の地域に散在する 70 個以上の単成火山より構成されている。

テフクロノロジーの成果によれば、東伊豆単成火山活動は 30,000 年前より 3,000 年前以降まで続いた。おそらくこの活動は実際には 30,000 年以前に始まったと考えられる。

この火山群の岩石の SiO₂ 含有量は bimodal な分布を示している。つまり、SiO₂ 49~60 wt% (玄武岩安山岩) までの範囲と、SiO₂ 68~74 wt% (デイサイト) である。玄武岩安山岩グループの斑晶組合せはカンラン石斜土長石、カンラン石+斜石+単斜輝石及びカンラン石斜+長石+単斜輝石斜方輝石である。安山岩は花崗岩質捕獲結晶 (石英、斜長石、ホルンブレンド及び不透明鉱物) を含んでいる。デイサイト質のドーム溶岩は、玄武岩質捕獲結晶 (カンラン石、斜長石及び単斜輝石) を含んでいる。

カンラン石+斜土長石斑晶組合せの岩石は、大部分がこの地域の北部に分布し、カンラン石+斜長石+単斜輝石の組合せは南部に分布している。カンラン石+斜長石+単斜輝石+斜方輝石の組合せは、南部の東側に集中している。花崗岩質捕獲結晶を含む岩石は、大部分が本火山群地域の北東部に分布している。

本火山群の岩石は SiO₂-アルカリ 変化図中で捕獲結晶を含まない岩石の大部分は高アルミナ玄武岩系区域に、捕獲岩を含む岩石のほとんどはソレライト岩系の区域にプロットされる。

玄武岩の無水溶融実験は、噴火前に玄武岩マグマ中にある程度の量の水が含まれていたことを示唆している。

本火山群の安山岩の大部分は、伊豆半島下の地殻を構成していると考えられる花崗岩と玄武岩質マグマの混成作用により生成されたと考えられる。これは、捕獲結晶の量と SiO₂ 含有量との正の相関及び希土類元素のデータから支持される。このような混成作用の事実を示す岩石は、大部分本地域の北東部に分布している。

石基の輝石組合せは、玄武岩中では普通輝石+ピジョン輝石又は普通輝石+ピジョン輝石+紫蘇輝岩から、安山岩中の普通輝石+ピジョン輝石+紫蘇輝石又は普通輝石+紫蘇輝石の組合せに変化する。この変化は混成作用に関連しており、紫蘇輝石を含む組合せは混成作用のより進んだ段階の産物である。

デイサイトマグマは、地殻を構成する花崗岩質岩の玄武岩マグマの熱による再溶融により生成されたと考えられる。これは、活動時期及び場所に関し、塩基性マグマと酸性マグマとの近接しての出現、デイサイト中にみられる玄武岩質捕獲結晶の存在及び塩基性マグマの花崗岩質捕獲岩と捕獲結晶の存在により支持される。

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