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Zoning type of a plagioclase in the volcanic rocks from the Myoko and Yakeyama volcanoes, Niigata Prefecture, Japan

Takanobu OBA* and Kenji HAYATSU**

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ABSTRACT

The volcanic rocks of the Myoko and Yakeyama in Quaternary are distributed in the Nishikubiki region, Niigata Prefecture. In the Myoko volcano, pyroxene and hornblende andesites are common, and basalt is accompanied in subordinate amount. The volcanic rocks from the Yakeyama are pyroxene - hornblende andesite and hornblende dacite.

The zoning types of plagioclase from these volcanic rocks are diverse. It is possible to be classified six types such as fresh, small dusty and big dusty zones at marginal or core parts, sieve-like and fingerprint-like textures. The major zoning type of plagioclase in andesite and dacite from the Yakeyama and Myoko volcanoes at the late stages are fresh type with normal zoning. The chemical variations of major and trace elements of the fresh plagioclase bearing volcanic rocks are plotted far distance from the differentiation trend. The plots of andesites with the various zoning types of plagioclase from the Myoko volcano are a wide dispersion in FeO/MgO-SiO_2 diagram.

KEY WORDS

Plagioclase, Magma mixing, Myoko volcanoes, Yakeyama

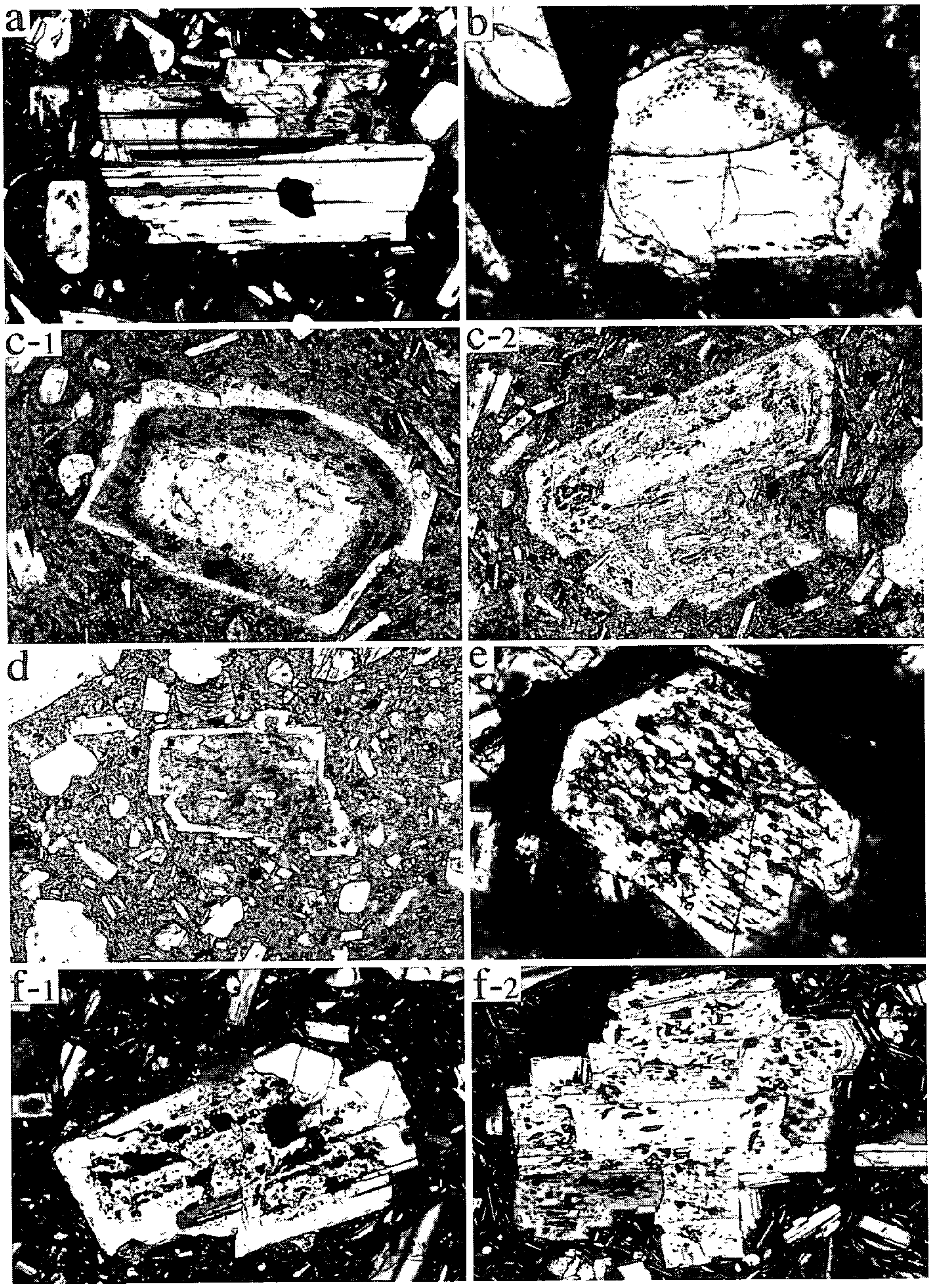
Introduction

The plagioclase in igneous rocks shows complex zoning consisting of corroded and dusty cores surrounded by calcic or sodic plagioclase. The textures of igneous plagioclase are fresh, dusty, sieve-like and honey-comb like. Vance (1965) reported that patchy zoning is the result of a two-stage replacement process involving partial resorption of early plagioclase crystals followed by crystallization of a more sodic plagioclase. Sakuyama (1981) concluded on the basis of the texture and chemical composition of plagioclase, and the disequilibrium phenocryst assemblages that calc-alkaline andesites from Myoko volcano were formed by mixing of basaltic and its derivative dacitic magmas. Therefore, plagioclase zoning comprises a unique record of past changes in magmatic environment.

In the experiments of the system diopside-albite-anorthite, Tsuchiyama (1985) report-

* Department of Geosciences, Joetsu University of Education, 943-8512 Joetsu, Japan

** Myoko Volcano Research Lavoratory, 944-0035 Arai, Japan


a
b
c-1
c-2
d
e
f-1
f-2

ed that dusty and resorved plagioclases were formed by the partial melting due to reaction between sodic plagioclase and a melt of intermediate composition in a mixed magma.

The record of past changes in magmatic environment was comprised in plagioclase zoning. We attempt to confirm the experimental results by the observation of dusty and resorbed plagioclases in the volcanic rocks from the Myoko and Yakeyama volcanoes.

Petrography of the volcanic rocks from the Myoko and Yakeyama volcanoes

In Myoko volcano, pyroxene and hornblende andesites are common, and basalt is accompanied in subordinate amount. Hayatsu (1977) reported that the Myoko volcano is divided into four active eruption stages. Hayatsu (1985) reported on the basis of the field geology and 14C dating that Yakeyama volcanic history is divided into four eruption stages. In the Yakeyama volcano, the majority of andesite is pyroxene- or pyroxene-free hornblende andesite and hornblende dacite.

The plagioclase occurs as phenocryst in volcanic rocks from the Myoko and Yakeyama volcanoes. The plagioclase has fresh, dusty, sieve-like and honey-comb like textures. Fig. 1 shows the photomicrographs of thin sections. The plagioclase with smooth interface is clear, as shown in Fig.1a. Plagioclase is ringed around a thin dusty and liquid inclusion at rim part (Fig. 1b). The dusty zone is extended from marginal part to core (Fig. 1c-1). A few plagioclase remains at core and marginal parts (Fig. 1c-2). plagioclase is resolved at core part (Fig. 1d), and dusty core is surrounded by crystal mantle (Fig. 1e). Liquid inclusions are scattered on the whole (Fig.1f-1). and are arranged along the zoning (Fig-1f-2).

Petrochemistry and discussion

Major and trace elements of the volcanic rocks were analyzed by X-ray fluorescence spectrometer (Rigaku S3030 model) at Joetsu University of Education. The chemical analysis data of the 29 volcanic rocks from the Yakeyama and Myoko volcanoes are given

Figure 1. Photomicrographs of thin sections showing the various textures of plagioclase in the volcanic rocks from the Myoko and Yakeyama volcanoes.
a: A fresh crystal with smooth interface (Yk-73: Yakeyama lava from the Yakeyama), b: A thin dusty and liquid inclusion ring at rim part (Tsubame lava from the Myoko), c-1: A wide dusty zone at marginal part (YK-73), c-2: A few plagioclase remains at core and marginal parts (YK-30: Diichi lava rom the Yakeyama), d: Dusty core is surrounded by crystal mantle (YK-73), e: Sieve-like texture (Mitaharayama lava from the Myoko), f-1: Liquid inclusions are distribed on the whole , and the core part is surrounded by mantle (YK-30), f-2: Liquid and dusty inclusions are distributed on the whole (YK-5-4: Hayakawa pyroclastic flow from the Yakeyama).

Table 1. The chemical compositions of major and trace elements, and zoning types of plagioclase in the volcanic rocks from the Yakayama volcano

	1	2	3	4	5	6	7	8
	YK	YK	YK	YK	YK	YK	YK	YK
	I	I	I	II	II	II	III	III
	Otani pf	Otani pf	Otani-II pf	Yakeyama lava	Tomariiwa lava	Akakurasawa lava	Icinokura lava	Maeyama lava
	46-3	105-1	103-1	73	60	51	45	38
SiO_2	59.51	61.03	59.82	60.17	61.09	62.62	58.38	61.13
TiO_2	0.68	0.62	0.67	0.61	0.61	0.55	0.70	0.60
Al_2O_3	16.65	16.95	17.35	17.18	17.07	16.70	17.59	16.88
FeO	6.96	6.37	6.84	6.41	6.29	5.67	7.14	6.34
MnO	0.14	0.13	0.14	0.13	0.13	0.12	0.15	0.14
MgO	3.73	2.96	3.18	3.21	3.01	2.65	3.57	3.16
CaO	7.15	6.61	6.89	7.01	6.46	6.18	7.61	6.53
Na_2O	3.10	3.04	2.93	3.10	3.08	3.04	2.81	3.01
K_2O	1.88	2.10	1.97	1.99	2.10	2.31	1.83	2.03
P_2O_5	0.19	0.18	0.19	0.17	0.16	0.15	0.20	0.17
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ba	306	356	347	354	323	323	307	377
Co	24	21	21	21	22	19	23	21
Cr	56	26	46	47	28	37	38	35
Cu	16	17	18	17	15	17	16	18
Nb	5.5	2.0	1.4	1.5	1.9	1.0	1.8	1.9
Ni	16	11	9	13	12	11	12	13
Rb	47	56	51	51	54	50	46	52
Sr	397	366	374	382	343	338	417	363
V	167	147	162	154	146	126	177	141
Y	19	21	19	20	21	21	20	20
Zn	64	61	66	61	59	52	65	63
Zr	112	112	109	110	108	111	111	111
Na_2O+K_2O	4.98	5.14	4.90	5.09	5.18	5.35	4.65	5.04
MgO/MgO+FeO	0.349	0.318	0.317	0.334	0.323	0.319	0.333	0.332
a	76	67.8	64.2	79.8	77.3	79.8	69.8	86.4
b	5.4	4	2.6	2.3	4.7	4.3	0.9	2.1
c-1	5.9	13.6	14.8	9.9	5.6	7.2	11.2	4.8
c-2	1.1	5.1	1.5	0.3	1.2	1.7	2.8	0.5
d	5.9	8.4	13.4	6.3	5.3	1.7	13.4	1.6
e	0	0	0	0	0	0	0	0
f-1, -2	5.6	1.1	3.5	1.4	5.9	5.2	1.9	4.5

pf: pyroclastic flow

Table 1. (Continued)

	9	10	11	12	13	14
	YK	YK	YK	YK	YK	YK
	III	III	III	III	IV	IV
	Daiichi lava	Hayakawa pf	Hayakawa pf	Hayakawa pf	Shinkawa lava	Yakeyamagawa lava
	29	5-4	5-5	1-5-1	69	42-1-2
SiO_2	58.18	60.57	61.51	59.73	64.32	60.92
TiO_2	0.68	0.61	0.61	0.65	0.49	0.60
Al_2O_3	17.18	17.17	16.83	17.11	16.83	17.21
FeO	7.18	6.42	6.28	6.85	5.05	6.26
MnO	0.14	0.13	0.13	0.13	0.11	0.13
MgO	4.14	3.24	3.05	3.52	2.13	3.08
CaO	7.68	6.69	6.37	6.97	5.38	6.68
Na_2O	2.85	3.02	2.98	2.93	3.18	2.92
K_2O	1.77	1.98	2.08	1.93	2.37	2.02
P_2O_5	0.20	0.17	0.16	0.18	0.14	0.17
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ba	302	310	348	309	361	360
Co	23	21	21	22	18	21
Cr	70	50	46	51	27	46
Cu	17	17	17	16	16	18
Nb	3.2	2.1	2.1	2.1	2.5	1.0
Ni	16	15	13	16	7	14
Rb	44	47	53	47	62	53
Sr	399	361	342	368	321	367
V	177	150	142	158	100	140
Y	20	19	20	19	21	20
Zn	65	60	59	60	51	64
Zr	107	107	108	109	113	110
Na_2O+K_2O	4.62	5.00	5.06	4.86	5.55	4.94
MgO/MgO+FeO	0.366	0.336	0.327	0.340	0.296	0.329
a	70.3	74.3	78.1	78.3	89.9	79.8
b	7	0.8	5.1	1	3.4	3.8
c-1	15	15.1	8.2	8.7	2.6	13.8
c-2	1	1.6	1.3	0.8	0	1.5
d	3.8	3.3	5.6	7.4	0.7	0.4
e	0	0	0	0	0.7	0
f-1, -2	2.9	4.9	1.8	3.8	2.6	0.8

Table 2. The chemical compositions of major elements and zoning types of plagioclase in the volcanic rocks from the Myoko volcano.

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo	Myo
	I	I	I	I	II	II	II	II	III	IV	IV	IV	IV	IV	IV
	Jigokudani lava	Kurobisiyama lava	Makunosawa lava	Byobuiwa lava	Maruyama lava	Ikenomine lava	Gohachigi lava	Kaname lava	Mitaharayama lava	Tubame lava	Myokosan lava	Nishikawadani lava	Nishikawadani scoria	Akakura pf	Otagirigawa pf
SiO_2	57.78	56.60	56.11	60.92	57.50	58.47	57.91	59.28	57.28	58.33	61.09	51.19	50.11	57.90	62.99
TiO_2	0.80	0.80	1.13	0.63	0.91	0.94	0.82	0.90	0.89	0.75	0.73	1.24	1.23	0.90	0.72
Al_2O_3	18.05	18.45	17.75	18.60	18.17	16.87	19.00	17.63	18.45	18.08	17.38	19.13	19.17	17.81	16.43
FeO	7.42	7.69	8.66	5.99	7.71	7.41	6.98	6.99	7.94	7.17	6.26	9.62	10.17	8.12	6.07
MnO	0.14	0.15	0.15	0.16	0.15	0.15	0.15	0.13	0.16	0.15	0.13	0.17	0.18	0.15	0.14
MgO	3.56	3.90	4.15	2.30	3.10	3.83	2.62	3.24	3.45	3.39	2.80	4.81	5.05	3.18	2.49
CaO	7.59	8.01	7.80	5.79	7.61	7.49	7.46	6.79	7.07	7.35	6.37	10.32	10.41	6.94	5.69
Na_2O	2.86	2.81	2.62	3.69	3.07	3.04	3.45	2.93	3.14	2.96	3.13	2.28	2.37	3.13	3.09
K_2O	1.65	1.48	1.46	1.72	1.64	1.66	1.38	1.94	1.47	1.67	1.97	0.98	1.06	1.72	2.22
P_2O_5	0.16	0.11	0.16	0.19	0.14	0.15	0.24	0.16	0.16	0.16	0.14	0.26	0.26	0.15	0.15
Total	100.01	100.00	99.99	99.99	100.00	100.01	100.01	99.99	100.01	100.01	100.00	100.00	100.00	100.00	99.99
Na_2O+K_2O	4.51	4.29	4.08	5.41	4.71	4.70	4.83	4.87	4.61	4.63	5.10	3.26	3.43	4.85	5.31
MgO/MgO+FeO	0.324	0.336	0.324	0.277	0.287	0.341	0.273	0.317	0.303	0.321	0.309	0.333	0.332	0.281	0.291
a	8.4	43.8	44.4	8.2	55.2	25.7	58.3	46.5	32.8	55	74.2	31.1	92.3	59.9	89.8
b	0.9	5.1	8.8	1.3	18.7	3.9	9.3	2.5	6.9	8	2.6	5.6	4.7	2.8	4.4
c-1	5.4	27.8	7.7	21.8	17.1	13.2	8.8	14.5	30.3	13.9	11.3	17.4	1	8	2.9
c-2	0.7	2.3	0	0	0	2.7	0	3.8	0.7	5.2	0.7	2.5	0	0.3	1.8
d	22.6	15.3	23.6	54.6	7.4	27.2	3.2	27.7	10.6	14.3	7	16.2	1.3	4.6	1.1
e	61.3	0	0.7	0	0	19.5	7.4	0.3	2.6	1.2	1	21.8	0	0.9	0
f-1, -2	0.7	5.7	14.8	14.1	1.7	7.8	13	4.7	16.1	2.4	3.3	5.3	0.7	23.5	0

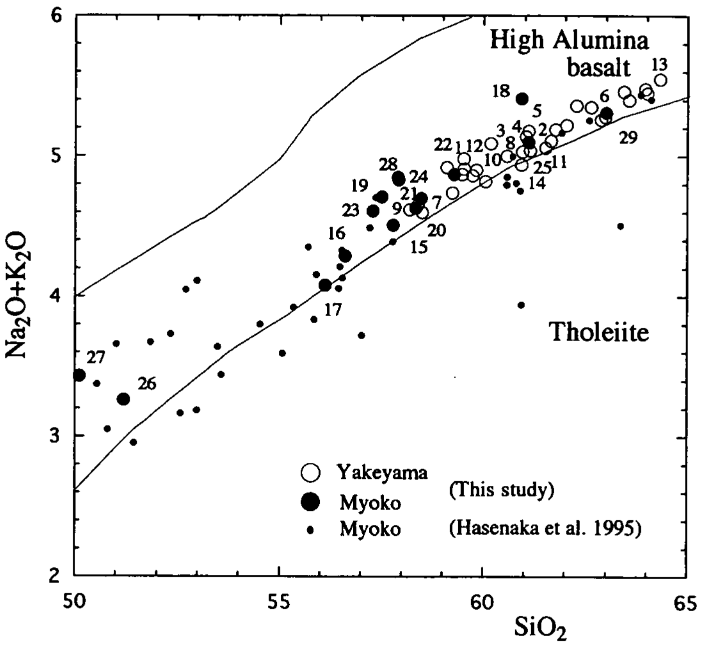


Figure 2. Na_2O+K_2O vs. SiO_2 variation diagram of the Myoko and Yakeyama volcanic rocks.

in Tables 1 and 2. The chemical compositions of plagioclase were analyzed with EDS (Link Isis 300) at the Joetsu University of Education. As compared with the volcanic rocks in the Myoko volcano, we used the data of major and trace elements of the volcanic rocks reported by Hasenaka et al. (1995).

Fig. 2 shows that Na_2O+K_2O increases with increasing SiO_2. The analytical data are plotted near the boundary of high alumina basalt and tholeiite. The plots of andesite and dacite from the Yakeyama volcano are fallen in the field of a high alumina basalt. The majority of andesites and dacites from the Myoko volcano in Fig. 2 are plotted on the variation curve except for 3 samples.

FeO/MgO vs. SiO_2 variation diagram (Fig. 3) indicates that the volcanic rocks from the Yakeyama volcano are plotted in the field of calc alkali rock., whereas those from the Myoko volcano are considerable scattered plots from tholeiite to calc alkali rock. The majority of zoning types of plagioclase in andesite and dacite from the Yakeyama and Myoko volcanoes at the late stages are fresh type with normal and oscillatory zonings. The proportion of the fresh type (A type) of plagioclase from these rocks is higher than 64 in Table 1. The arrow in Fig. 3 indicates the differentiation trend of whole-rock chemical composition deduced from chemical trends of the normal zoning plagioclase bearing rocks (N-type) reported by Sakuyama (1981). The Myoko volcanic rocks contained plagioclase with the large amounts of dusty core and inclusion belt are plotted far distances from the hypothetical differentiation trend. Nos. 19, 21and 28 samples in Table 2 plotted near the

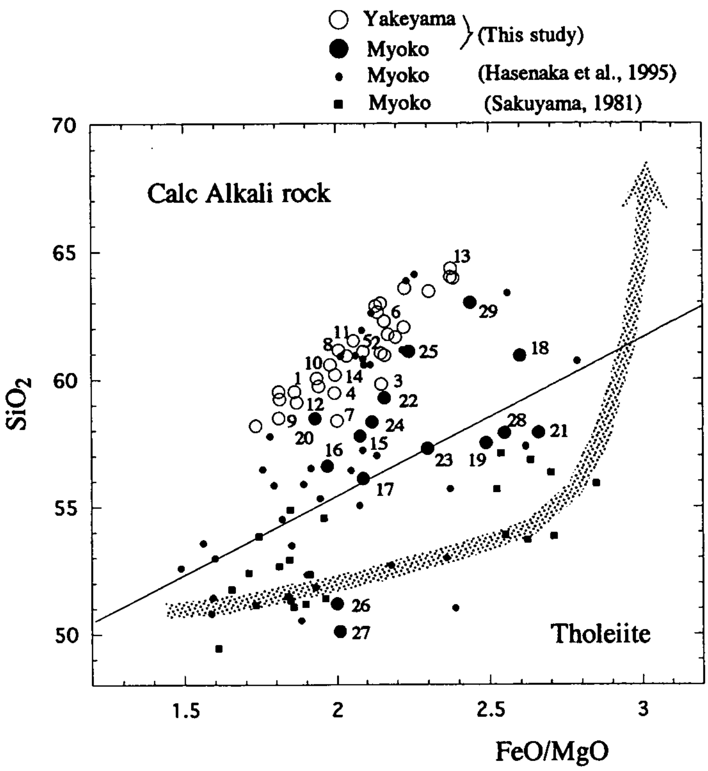


Figure 3. FeO/MgO vs. SiO_2 variation diagram of the Myoko and Yakeyama volcanic rocks. The arrow indicates the differentiation trend of whole-rock chemical composition of N-type rocks reported by Sakuyama (1981).

differentiation trend have the higher proportion of a fresh plagioclase, as compared to Nos. 20 and 22.

The variations of trace elements suggest the similar trends, as shown in Fig. 4. In the volcanic rocks from the Yakeyama volcano, Ba and Rb increase with increasing SiO_2, on the other hand Sr, Co and V decrease, Y. Zr and Cu are constant. The trace elements of the volcanic rocks from the Myoko volcano indicate considerable scattered plots.

Sakuyama (1981) reported that the N-type and reverse zoning plagioclase bearing rocks (R-type) were plotted in different regions. He explained that the R-type rocks are formed by mixing of basaltic and each derivative magma at each stage. The volcanic rocks from the Yakeyama are plotted on the line of basalt and its derivative dacite.

The line analyses from core to rim of plagioclase indicate that the dusty plagioclases are some normal and oscillatory zonings in the Yakayama and the only reverse zonings in the Myoko. Vance (1965) reported that patchy zoning is the result of a two-stage replacement process involving partial resorption of early plagioclase crystals followed by

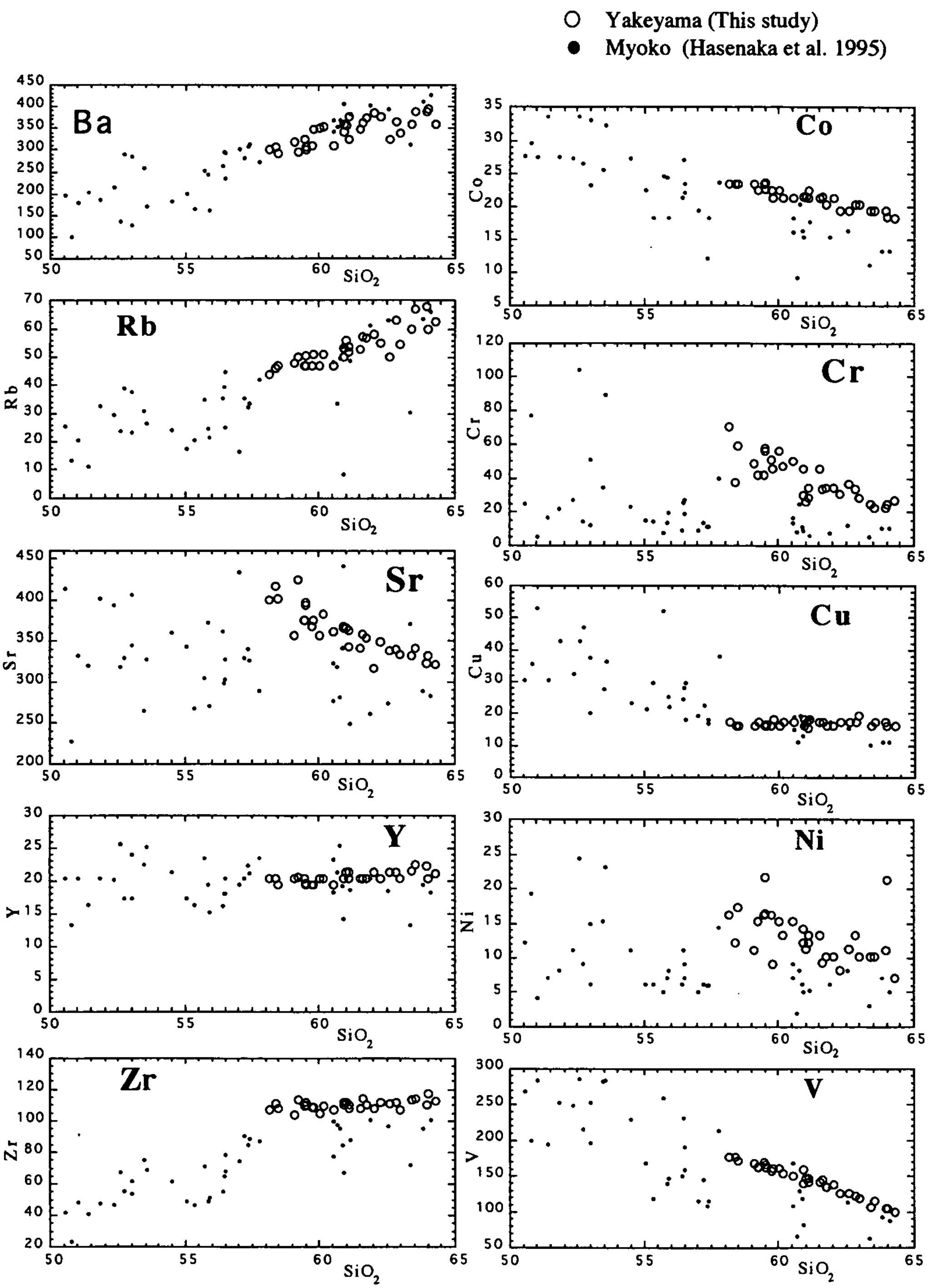


Figure 4. Trace elements vs. SiO_2 variation diagrams of the Myoko and Yakeyama volcanic rocks.

crystallization of a more sodic plagioclase. In this case, the zoning pattern of the dusty plagioclase is normal. Tsuchiyama (1985) reported that dusty and resorved plagioclases were formed by the partial melting due to reaction between sodic plagioclase and a melt of intermediate composition in a mixed magma. Calcic plagioclase does not react with a melt of intermediate composition. Although the peak composition of plagioclase at the core part from the Yakeyama volcano is about 50 mol % An, the majority of zoning type are fresh normal and oscillatory. Dusty plagioclase with reverse zoning is a few.

The chemical compositions of the whole-rocks supported that the end members of mixing magma are basaltic and its derivative magmas for the Myoko and Yakeyama volcanoes. However, the ratios of fresh and dusty plagioclases do not support the mixing ratios of basaltic and dacitic magmas.

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