Petrochemical Studies on the Active Volcanoes in Japan

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By

Sadakatu TANEDA

Contents

Introduction

There are as many as 49 active volcanoes in Japan, with good results of chemical analyses of lavas, which are divided into 2 groups as follows:

group

I Volcanoes which have ejected lavas in historic times.

A few volcanoes which have ejected considerable amount of bombs or pumices, not accompanied with lava flow, in historic times are also treated.

II Volcanoes which have never ejected lava (flow) in historic times.

In this paper the general description on petrochemical properties of the lavas of historic times is given, with reference to the lavas of prehistoric times belonging to groups I and II.

Besides the stastic studies, the investigation of the various phenomena of an individual eruption as well as the properties of products is also significant. Standing such a viewpoint some considerations of the structure and eruption mechanism of the Sakura-zima volcano are given as an appendix.

Acknowledgement

I acknowledge the contribution made by many investigators and analysts, whose names are reluctantly not listed here (Refer to Table 1・1–3).

Fig. 1. Volcanoes with analytical data of lavas published before April 1961
Circles with dot in centre: Active volcanoes which have ejected lavas in historic times (group I).
Open circles: Active volcanoes which have apparently never flowed out lava in historic times (group II).
Solid circles: Volcanoes with no recorded eruptions.

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I. Properties of lavas

The properties of the lavas (lava flow and a few bombs or pumices produced by the distinctive eruptions) of historic times are listed in Table 1.

Table 1-1. Lavas (lava, bomb, pumice) of historic times in Japan

Name of volcano	Year of distinct eruption	Properties of analysed lavas									Number of analyses; Remark
		Mode of occurrence	Rock name*	SiO_2	Total FeO	MgO	Alkalies	Norm			
								Or	Ab	An	
Tokati-dake	1925-26	Mud flow bomb	Ao 2p	53.93	53.2	22.6	24.2	13	32	55	
Tarumai	1909	Dome	A 2p	59.17	58.2	21.8	20.9	11	30	59	5
	1909	Bomb	A 2p	57.88	57.5	21.5	21.0	10	32	58	3
Usu	Pre 900	Dome	D(a) hy	71.25	44.6	7.7	47.6	13	64	34	
	1822(−) 1857	Dome Mud flow fragm.	D(a) hy	69.43	38.6	8.9	52.5	12	58	30	2
	(1910	Ejecta	A 2p	52.40	54.4	19.5	25.9	16	39	45	not essential?)
	1944-45	Dome	D hy a	69.74	41.3	8.9	49.9	16	54	31	
Komaga-dake	1928-29	Pumice flow, bomb, ejecta	A a hy	60.43	50.2	17.9	32.0	9	54	37	8
Iwate	1719	Lava flow	A(o) a hy	53.65	58.3	24.8	16.9	3	34	63	
Tyōkai (Chokai)	1801	Dome	A a hy	60.62	44.3	19.1	36.6	20	45	35	
Asama	1783	Lava flow	A(o) hy a	61.38	43.2	25.5	31.3	13	44	44	2
		Ejecta	A(o) hy a	61.52	43.3	24.4	32.3	13	49	38	2
	(1930	Bomb	A	59.67							Alk. : n.d.)
	1929 (and 1927-32)	Bomb	A(o) hy a	60.03	45.6	26.4	28.0	10	41	49	2
Huzi (Fuji)	864	Lava flow	B (2p) o	51.30	55.3	26.6	18.0	7	34	59	
	1707	Scoria	Ba o	50.95	55.9	26.2	17.9	7	38	54	2
	1707	Ejecta	Aa	65.81	41.1	11.8	47.1	24	49	27	4

* B—Basalt A—Andesite D—Dacite A(o) hy a—Olivine-bearing hypersthene-augite andesite p—pyroxene

Tada, H. & Tsuya H. (1927): Bull. Earthq. R. I., 2; Suzuki, J. (1935): Bull. Volc. S. J., **2**; Katsui, Y. & Takahasi, T. (1960): Jour. Jap. As. P.M.E'G., **44**; Ishikawa, T. (1952): Jour. Fac. Sc. Hokkaido Univ., IV, **7**; Katsui, Y. (1959): Bull. Geol. Com. Hokkaido, No. 38; Sato, D. (1913); Geol. Surv.; Yagi, K. (1953): Trans. Am. Geoph. Un., 34; Sedo, K. (1931): Jour. Jap. As. P.M.E'G., **6**; Sedo, K. & Yagi, T. (1931): Jour. Jap. As. P.M.E'G., **5**; Tsuya, H. (1929): Bull. Earthq. R.I., **7**; Kawano, Y. & Aoki, K. (1959): Sc. Rep. Tohoku Univ., III, **4**; Ōnuma, k. (1954): oral com., Katsui, Y. (1954): Jour. Geol. S.J. **60**; Kozu, S. (1932): Bull. Volc. S.J., 1; Tsuya, H. (1933): Geog., **2** & Bull. Earthq. R.I., **11**; Iwasaki, I. (1935): Jour. Chem. S.J., **56**, (1936): Do., **57**; Tsuya, H. (1937); Bull. Earthq. R.I., **15**;

Table 1-2

Name of volcano	Year of distinct eruption	Properties of analysed lavas									Number of analyses; Remark
		Mode of occurrence	Rock name*	SiO_2	Total FeO	MgO	Alkalies	Norm			
								Or	Ab	An	
Mihara-yama	1330±	Lava flow	B	52.5	64.6	24.1	11.3	5	36	59	9
(O-sima)	1421?	Lava flow	B	52.2	63.9	24.7	11.2	5	34	61	7
	1552?	Lava flow	B(o)	52.3	64.7	23.7	11.4	5	34	61	3
	1684	Lava flow	B	52.2	64.8	23.6	11.4	5	35	60	5
	1778	Lava flow	B	51.7	65.3	23.3	11.2	5	35	61	5
	1912	Lava flow	B hy	51.67	66.6	24.1	9.3	4	22	73	5
	1950-51	Lava flow	B hy a	52.45	66.4	23.5	10.1	4	28	68	
Miyake-zima	1643?	Lava flow	B	51.80	65.4	21.1	13.5	5	41	55	Aphiric
	(1712	Lava flow)									
	1874	Lava flow	Ao(hy) a	53.46	65.3	18.6	16.1	8	38	55	4
	1940	Lava flow, Lapilli	Bo	52.57	62.1	23.2	14.6	6	37	58	Lapilli
Myozin-syo	1952	Pumice with gray patch	D hy a	68.23	42.2	14.2	43.6	8	60	33	White part
	1952	Gray patch	D 2p q	63.30	52.7	22.0	27.3	5	42	52	
	1952	Pumice	D 2p q	65.39	45.9	13.8	40.3	6	56	38	White
	(1953	Ash		63.57	46.3	20.6	33.1	8	52	40)	
	1960	Pumice with	D 2p	68.49	34.6	13.7	51.6	9	58	33	
	1960	Dark stripe	A	57.82	53.5	23.0	23.5	6	43	50	
Tori-sima(Tonan)	1939	Lava flow	BA a hy	54.51	60.3	22.7	16.9	3	41	57	

Tsuboi, S. (1917): Jour. Geol. S.J., **24**, (1918); Do., **25**; Tsuya, H. & Morimoto, R. (1951): Bull. Earthq. R.I., **30**; Kuno, H. (1958): Bull. Volc. S.J., **3**; Katsura, T. & Nakamura, K. (1960): Bull. Volc. S.J., **5**; Isshiki, N. (1960): Expl. Text Geol. Map (Miyake-zima); Morimoto, R. (1957): CGI, xx., (1960): Assembly Volc. S.J., Tanakadate, H. (1940): Jour. Geol. S.J., **47**; Tsuya, H. (1937): Bull. Earthq. R.I., **15**;

Table 1-1~3 Abbr. R.I. Research Institute, S.J. Society of Japan

P.M.E'G. Petrologist, Mineralogist and Economic Geologist * refer to Table 1-1

Table 1-3

Name of volcano	Year of distinct eruption	Properties of analysed lavas									Number of analyses; Remark
		Mode of occurrence	Rock name*	SiO_2	Tatal FeO	MgO	Alkalies	Norm			
								Or	Ab	An	
Iwo-zima (Volc. Is.)	1914	Pumice	TA o p	60.82	27.9	11.1	61.0	31	60	9	
Aso	1929	Ejecta	A o 2p	53.52	49.5	22.5	27.9	16	39	45	
	1933	Bomb	A o 2p	52.66	46.8	23.4	29.9	16	45	39	
	1958	Scoria block	A hy a	53.50	49.7	21.3	29.0	15	47	38	2
Unzen	1657-63	Lava flow	A o b h	57.11	43.9	26.1	30.0	16	38	46	3
	1792	Lava flow	A b h	65.37	33.2	17.2	49.7	19	48	32	3
Sakura-zima	1471-76	Lava flow	A 2p	66.35	43.1	11.6	45.4	16	50	34	4
	1779	Lava flow	A 2p	64.13	46.1	13.6	40.1	16	51	33	4
	1914	Lava flow	A 2p	61.04	46.7	18.3	34.8	14	44	42	3
	1914	Lava flow	A 2p	59.01	47.0	24.0	28.8	14	37	48	2
	1939	Bomb	A o 2p	57.11	48.4	24.1	27.6	13	42	46	4
	1946	Lava flow	A 2p	61.25	50.7	19.3	30.0	15	38	47	2
	1956-	Bomb	A 2p	59.69	49.0	17.9	33.1	13	44	44	
Iwo-zima (Satunan)	1934	Lava flow	A a hy	64.51	39.6	19.0	41.4	15	46	39	3
	1934	Pumice, Bomb	A 2p	69.72	42.5	13.3	44.2	16	52	32	2
Suwanose-zima	1813	Lava flow	A	60.01	46.2	18.4	35.4	16	45	40	
	1884-89?	Lava flow	A	59.97	47.7	17.9	34.4	15	44	41	
	1952?	Bomb	A	57.83	50.3	18.4	31.3	15	45	41	2

Tsuya, H. (1936): Bull. Eatrhq. R.I., **14**; Iwasaki, I. (1937): Jour. Chem. S.J., **63**; Kawano, Y. (1933): Jour. Jap. As. P.M.E'G., **12**; Homma, H. & Mukae, M. (1938); Bull. Volc. S.J., **4**; Matsumoto, H. (1958): Jour. Jap. As. P.M.E'G., **43**; Taneda, S. (Aso, unpublished); Homma, H. (1936): Bull. Volc. S.J., **3**; Kurasawa, H. & Takahasi, K. (1959): Assembly Geol. S.J.; Yamamoto, T. (1960): Bull. Volc. S.J., **5**; Yamaguchi, K. (Taneda, S. 1952: Guide Book—Sakura-jima, Kyushu Univ.); Morimoto, R. (1948): Bull. Earthq. R.I., **26**; Taneda, S. & Morita, J. (1958): Jour. Jap. As. P.M.E'G., **42**; Tanakadate, H. (1935): Proc. Imp. Ac. Tokyo, **11**; Matsumoto, H. (1954): Kumamoto J.S., BI, 1, (1956); Do., **2**; Abbr. b—biotite, h—hornblende, T—trachytic,
* refer. to Table 1-1

Table. 2-1. Average (except column V) chemical compositions of lavas (including few bombs & pumices) of historic times in Japan

No. of anal.	I 20	II 10	III 12	IV 9	V 1
SiO_2	52.56	58.53	61.73	67.61	71.25
TiO_2	1.18	0.72	0.65	0.57	0.43
Al_2O_3	16.47	17.17	16.18	15.23	13.21
Fe_2O_3	3.30	2.41	2.20	1.62	3.19
FeO	8.50	5.38	4.32	2.88	1.96
MnO	0.20	0.27	0.15	0.11	0.27
MgO	4.44	3.19	2.75	1.36	0.84
CaO	9.65	7.66	6.11	4.36	3.10
Na_2O	2.40	2.87	3.49	3.68	4.02
K_2O	0.77	1.31	1.55	1.38	1.15
H_2O+	0.29	0.52	0.51	0.60	0.50
H_2O-	0.29	0.24	0.21	0.27	0.20
P_2O_5	0.18	0.19	0.18	0.18	0.46
Total	100.22	100.46	100.03	99.85	100.63
$\frac{Al_2O_3}{CaO}$	1.70	2.24	2.65	3.49	3.49
$\frac{Na_2O}{K_2O}$	3.11	2.19	2.25	2.66	4.25
$\frac{\text{Total FeO}}{MgO}$	2.62	2.44	2.36	3.26	11.10
$\frac{Al_2O_3}{Na_2O+K_2O}$	3.19	4.10	3.21	3.00	2.55
$\frac{Fe_2O_3}{FeO}$	0.38	0.44	0.46	0.56	0.31
Total FeO	60.1	50.6	44.67	40.3	44.6
MgO	23.3	21.4	19.5	12.7	7.7
Na_2O+K_2O	16.6	28.0	35.8	47.1	47.6

I $50 \leqq SiO_2 < 55$, II $55 \leqq SiO_2 < 60$, III $60 \leqq SiO_2 < 65$, IV $65 \leqq SiO_2 < 70$

II. Conparison of the lavas of historic times and those of prehistoric times in the average chemical composition

The average chemical composition of the lavas of historic times (Table 2·1), compared with those of prehistoric times (Table 2·2) are characterized by low K_2O, $H_2O(+)$, and Fe_2O_3/FeO, and high FeO (Total) (distinct at $SiO_2<60$, >70), MnO (distinct between SiO_2 50 and 60), Na_2O/K_2O ($SiO_2>55$), Al_2O_3/Na_2O+K_2O ($SiO_2<60$,

Table 2-2. Average chemical compositions of lavas (lava, bomb, pumice) of prehistoric times of Japanese active volcanoes which have ejected lavas in historic times

No. of anal.	I 7	II 25	III 19	IV 20	V 6	VI 3
SiO_2	49.21	52.23	58.11	61.40	66.11	71.71
TiO_2	1.02	1.07	0.70	0.72	0.59	0.54
Al_2O_3	17.89	17.59	17.00	16.61	15.24	14.15
Fe_2O_3	3.84	3.42	3.00	2.98	1.87	0.93
MnO	0.18	0.20	0.19	0.13	0.09	0.11
MgO	5.29	4.40	3.36	2.76	1.40	0.29
CaO	10.62	9.53	7.03	5.96	4.43	2.18
Na_2O	2.06	2.61	3.10	3.11	3.66	4.25
K_2O	0.60	0.72	1.46	1.81	2.11	3.13
H_2O+	0.50	0.49	0.64	0.71	0.63	0.87
H_2O-	0.24	0.26	0.40	0.51	0.54	0.40
P_2O_5	0.17	0.18	0.20	0.17	0.21	0.07
Total	99.90	100.18	100.14	100.27	100.24	100.01
$\frac{Al_2O_3}{CaO}$	1.68	1.84	2.41	2.78	3.44	6.49
$\frac{Na_2O}{K_2O}$	3.43	3.62	2.12	1.71	1.73	1.35
$\frac{\text{Total FeO}}{MgO}$	2.25	2.42	2.32	2.28	3.66	8.34
$\frac{Al_2O_3}{Na_2+K_2O}$	6.72	5.28	3.72	3.37	2.64	1.91
$\frac{Fe_2O_3}{FeO}$	0.46	0.46	0.60	0.85	0.55	0.67
Total FeO	59.5	57.5	49.1	44.6	41.3	23.2
MgO	26.9	24.2	21.6	19.9	11.5	2.9
Na_2O+K_2O	13.5	18.3	29.3	35.5	47.3	73.9

I $SiO_2<50\%$, II $50\leqq SiO_2<55$, III $55\leqq SiO_2<60$, IV $60\leqq SiO_2<65$, V $65\leqq SiO_2<70$
VI $70\leqq SiO_2<75$

>65) and Total FeO/MgO (SiO_2<65, >70).*

The alkali-lime index is 64.4 for all lavas of historic times of Japanese active volcanoes, while it is 63.6 for lavas of prehistoric times of the same volcanoes. On the other hand it is noticed that in general the index increases towards the inner side (the Japan Sea coast) of the Japan Islands (Taneda, 1951; Ishikawa & Katsui,

* If all of the specimens for analyses are fresh compretely, the differences in the values of H_2O and Fe_2O_3/FeO are significant for the studies of volcanism.

Table 3. Classificaton of lavas (and bomb and pumice) of historic and prehistoric times according to the silica quantities and localities

SiO_2	$SiO_2 < 50$	$50 \leqq SiO_2 < 55$	$55 \leqq SiO_2 < 60$	$60 \leq SiO_2 < 65$	$65 \leqq SiO_2 < 70$	$75 \leqq SiO_2 < 75$	$75 \leqq SiO_2$
Products of historic times		Tokati-dake Usu (?) Iwate Huzi Mihara-yama Miyake-zima Tori-sima Aso	Tarumai Asama Myozin-syo Unzen Sakura-zima Suwanose	Komaga-dake Tyokai Asama Myozin-syo Iwo-zima (Volc. Is.) Sakura-zima Suwanose	Huzi Myozin.syo Unzen Sakura-zima Iwo-zima (Satunan)	Usu	
Products of pre-historic times	Tokati-dake Huzi Miyake-zima Tori-sima	Tokati-dake Usu Iwate Mihara-yama Miyake-zima Tarumai Aso	Tarumai Komaga-dake Iwate Asama Unzen Iwo-zima (Satunan) Suwanose	Tokati-dake Tarumai Komaga-dake Asama Unzen Sakura-zima Suwanose	Usu Aso Unzen Sakura-zima Iwo-zima (Satunan)	Asama Aso	

1959).

Consequently the characteristics of the lavas of historic times are referred largely to the **geographical distribution** of active volcanoes in this region.

III. Frequency distribution

a. Frequency distribution of lavas based on the silica percentage

The curve of frequency distribution of lavas of historic times based on the silica percentage is as shown in Fig. 2 characterized by two peaks, one (the highest peak) between 52 and 53 and two (a lower peak) between 59 and 61 in the silica percentage. The former is caused by the products of the Mihara-yama (Ô-sima), Miyake-zima,

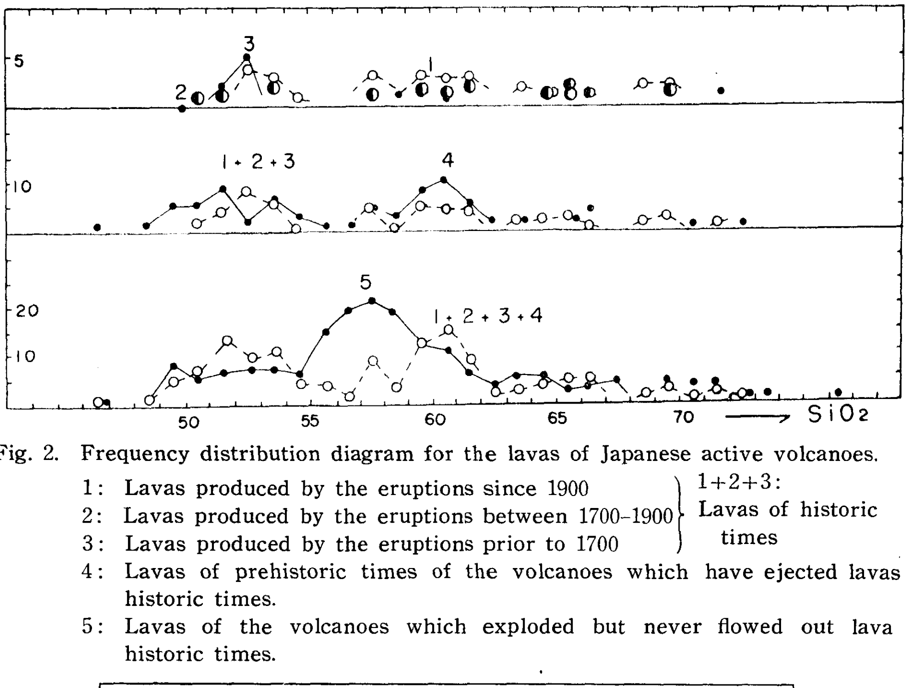

Fig. 2. Frequency distribution diagram for the lavas of Japanese active volcanoes.

1: Lavas produced by the eruptions since 1900
2: Lavas produced by the eruptions between 1700–1900
3: Lavas produced by the eruptions prior to 1700
(1+2+3: Lavas of historic times)
4: Lavas of prehistoric times of the volcanoes which have ejected lavas in historic times.
5: Lavas of the volcanoes which exploded but never flowed out lava in historic times.

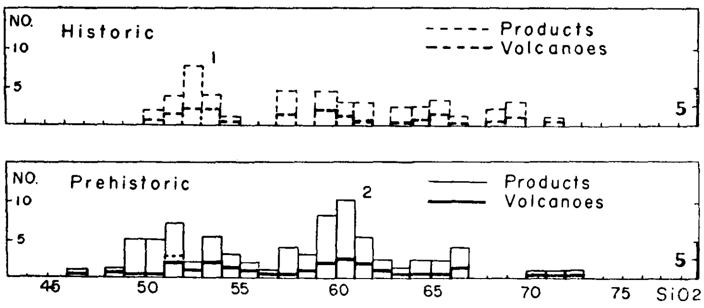

Fig. 2-b. Frequency distribution of active volcanoes which have ejected lavas in historic times and that of their essential products (lavas).
The Frequency distribution of volcanoes are based on the silica percentages of their products.

Aso and Usu (?) volcanoes, and the latter is caused by those of the Asama, Sakura-zima, Komaga-dake (Hokkaido), Tarumai, Iwo-zima (Volcano Islands) and Swanose-zima volcanoes (Table 3 and Fig. 2b).

The curve for the lavas of prehistoric times has the highest peak between 60 and 61, and the second peak between 51 and 52. The former is caused by the products of the Tokati-dake, Tarumai, Unzen, Sakura-zima and Suwanose-zima volcanoes, and the latter is caused by those of the Mihara-yama, Huzi, and Miyake-zima volcanoes (Table 3 and Fig. 2b). In Fig. 2b it is noticed that the frequency peaks for products are well corresponding to the peaks for volcanoes.

It should be significant that the frequency distribution curve for the lavas of Japanese active volcanoes shows two peaks, and that the frequency peaks for lavas

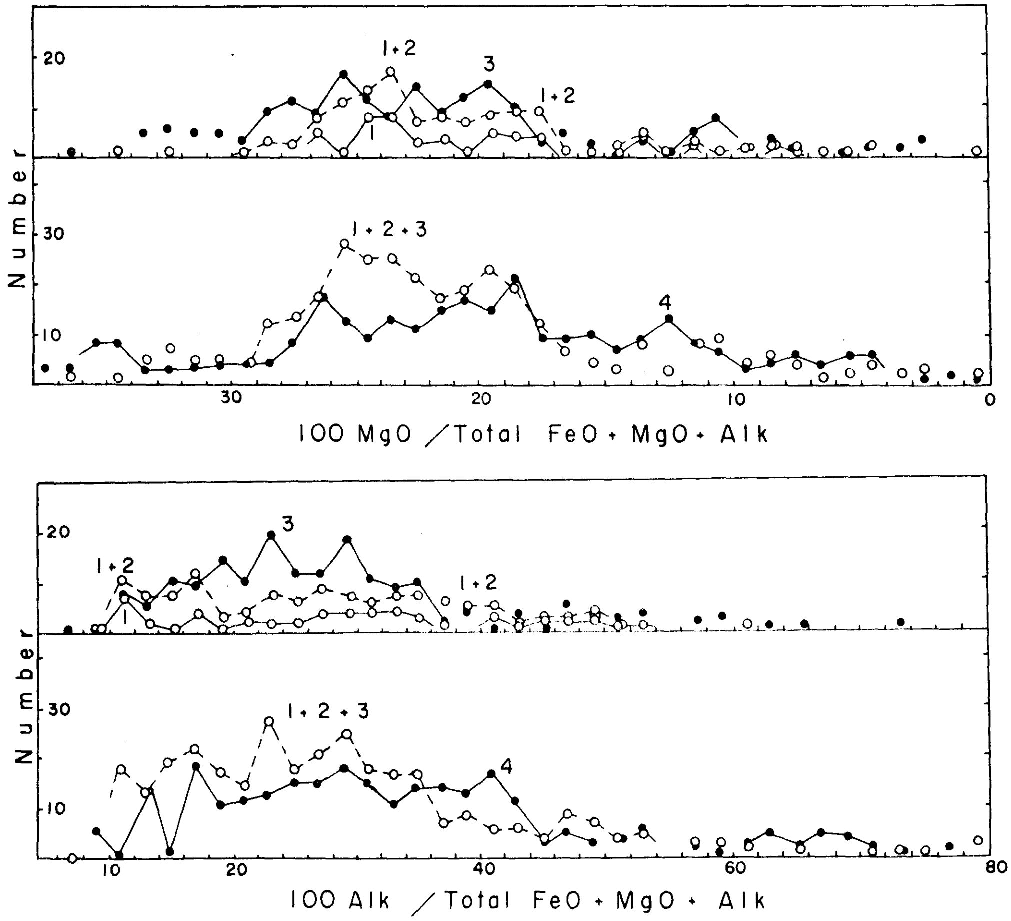

Fig. 3. Frequency distribution diagram for the lavas of Japanese active volcanoes.
1: Lavas of historic times.
2: Lavas of prehistoric times of the volcanoes which have ejected lavas in historic times.
3: Lavas of the volcanoes which exploded but never flowed out lava in historic times.

are well corresponding to the peaks for volcanoes.

b. Frequency distribution of lavas based on the Alk/Total FeO+MgO+Alk ratio

The ratio MgO:(Total FeO+MgO+Alk) of all analytical results were calculated. The curves for frequency distribution are shown in Fig. 3.

c. Frequency distribution of lavas based on the MgO/Total FeO+MgO+Alk ratio

The curves for frequency distribution are shown in Fig. 3.

d. Remarks

It is noticed that the frequency curves based on 100 Alk/Total FeO+MgO+Alk show similar characteristics to those based on the silica percentage, which are slightly different from those based on the 100 MgO/Total FeO+MgO+Alk ratio. In any case all the frequency distribution curves for the lavas of volcanoes which have ejected lavas in historic times, show two principal peaks, which correspond to the peaks of frequency distribution of the volcanoes (Fig. 2b). This is a distinct fact to be noticed by petrologist as well as volcanologist.

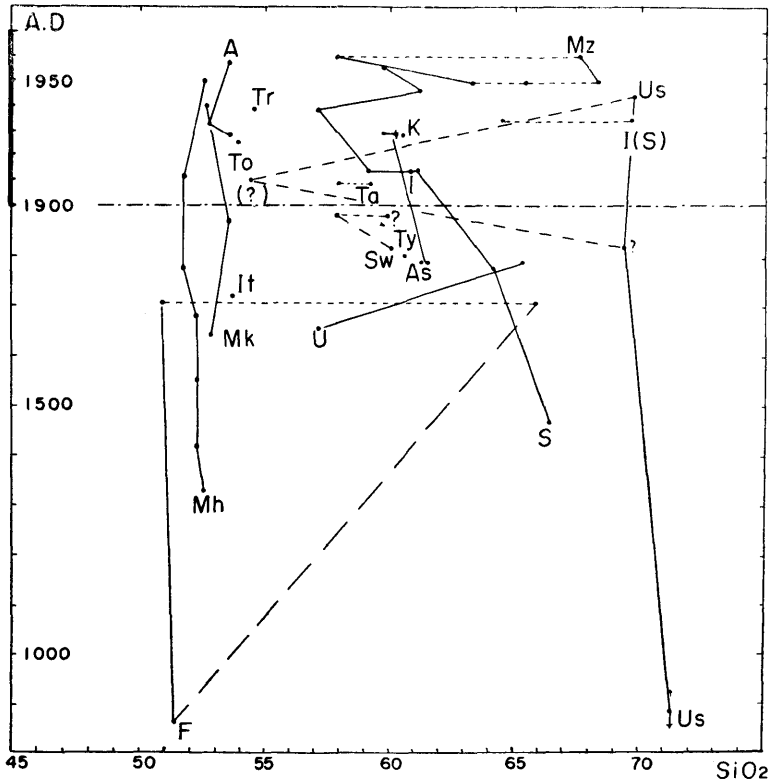

Fig. 4. Abbr. A Aso, As Asama, F Fuji (or Huzi), I Iwozima, Volc. Is, I (s) Iwo-zima, Satunan, It Iwate, K Komaga-dake, Hokkaido, Mh Mihara, Osima, Mk Miyake-zima, Mz Myozin-syo, S Sakura-zima (Sakurajima), Sw Suwanose-zima, Ta Tarumai, To Tokati-dake, Tr Tori-sima, Izu, Ty Tyokai, U Unzen, Us Usu.

IV. The variation trend of chemical composition of lavas throughout historic times

a. The variation of SiO_2, MgO/Total FeO+MgO+Alk and Alk/Total FeO+MgO+Alk

On arranging the SiO_2 percentages and the 100 MgO/Total FeO+MgO+Alk and 100 Alk/Total FeO+MgO+Alk ratios according to the eruption period, it becomes manifest that (1) the silica content of the lavas have increased during the last period of the growth of each volcano (Fig. 4), with exception of the last products of Miyake-zima and Asama which more or less decreased in the silica; (2) The ratio MgO: (Total FeO+Alkalies) of the last products of all volcanoes with exception of Miyake-zima have decreased (Fig. 5); and (3) The ratio Alkalies: (Total FeO+MgO) of the last product of all volcanoes with exception of Miyake-zima, Asama and Suwanose-zima have increased (Fig. 6).

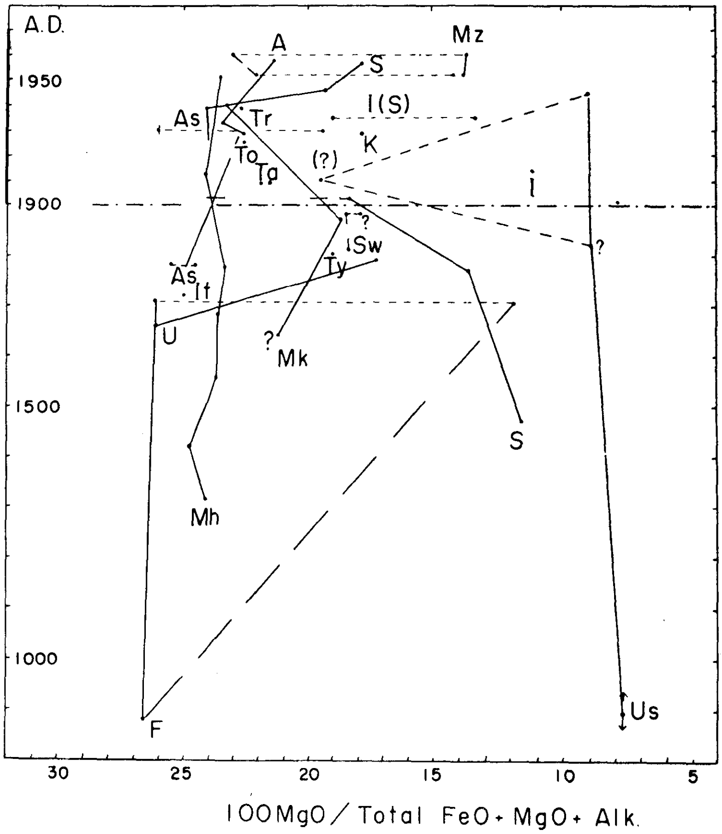

Fig. 5. Abbr. refer to Fig. 4.

b. Sequence in the triangular Total FeO–MgO–Alk diagram

Most of the volcanoes except Miyake-zima have increased more or less in Total

FeO at the last eruption period. Some of them have decreased in Alkalies, i.e. Asama, Mihara-yama and Suwanose-zima, and some of them have increased in Alkalies i.e. Sakura-zima and Unzen (Fig. 7).

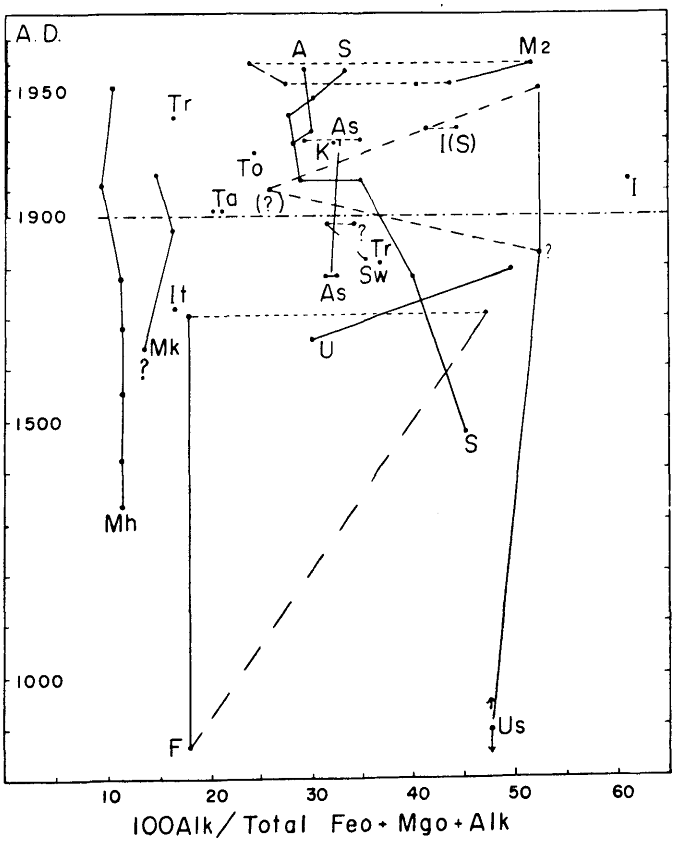

Fig. 6. Abbr. refer to Fig. 4.

Consequently the newer lavas occupy an elongated area perpendicular to the Total FeO–MgO ridge ranging from a certain point near the Total FeO–MgO ridge to a certain point near the Alkali apex, compared with the older ones (Fig. 8).

c. Normative feldspar

Description is not given here. See Fig. 7.

V. Comparison of the lavas of historic times and those of prehistoric times in the ratio Total FeO : MgO : Alkalies

The lavas of historic times are plotted on the triangular diagram for the ratio Total FeO : MgO : Alkalies, along with those of prehistoric times (Fig. 9). A glance at the diagram show the relation of the lavas of historic times to those of prehistoric times, which are classified into seven types as follows (1–7 of Table 4 &Fig. 10):

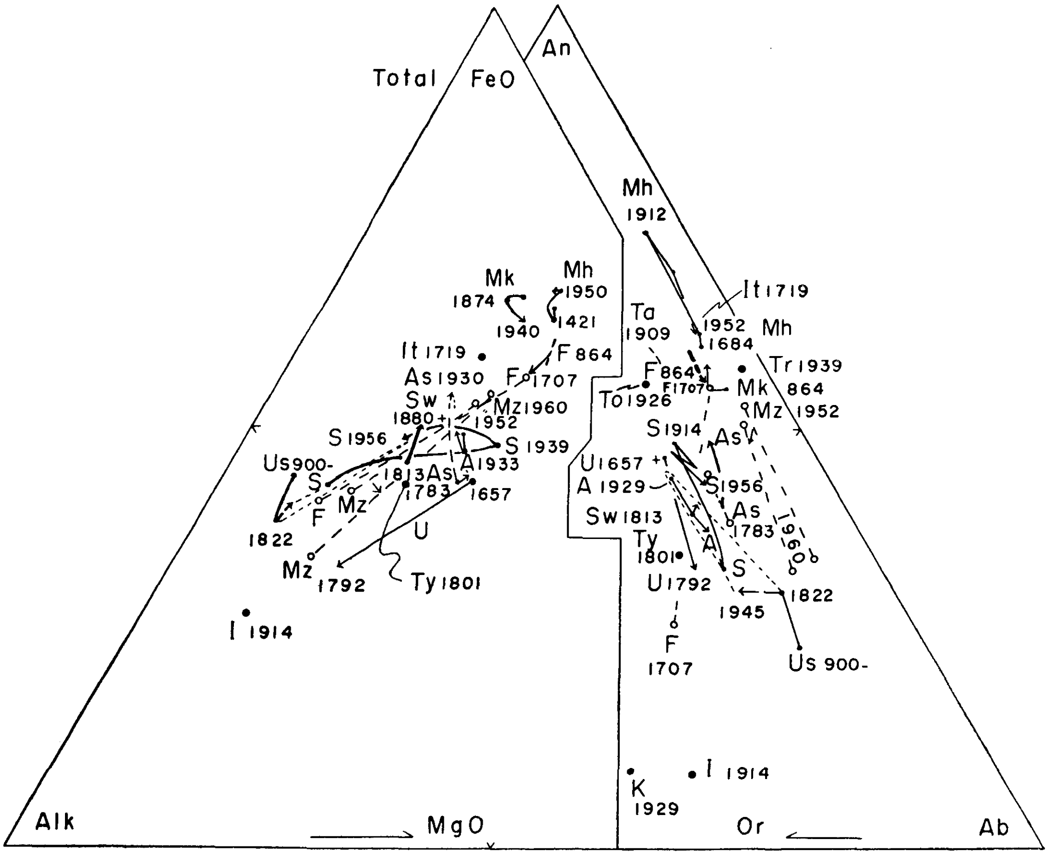

Fig. 7. Abbr. refer to Fig. 4.

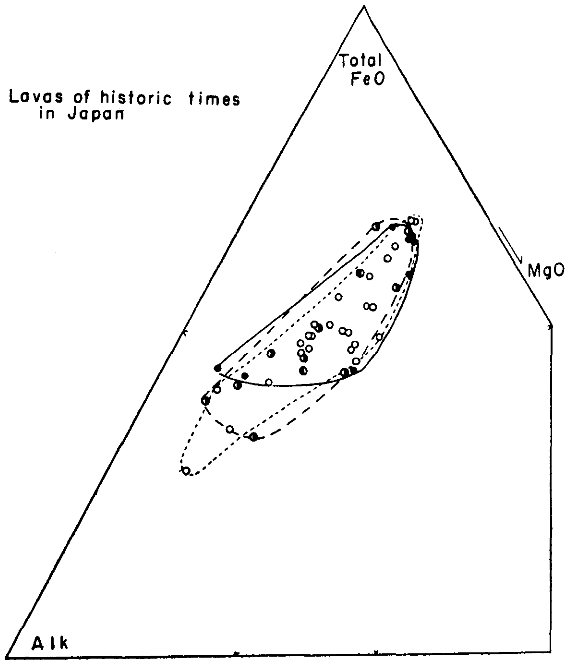

Fig. 8. Open circles: Lavas since 1900
Semi solid circles: Lavas between 1700-1900
Solid circles: Lavas prior to 1700

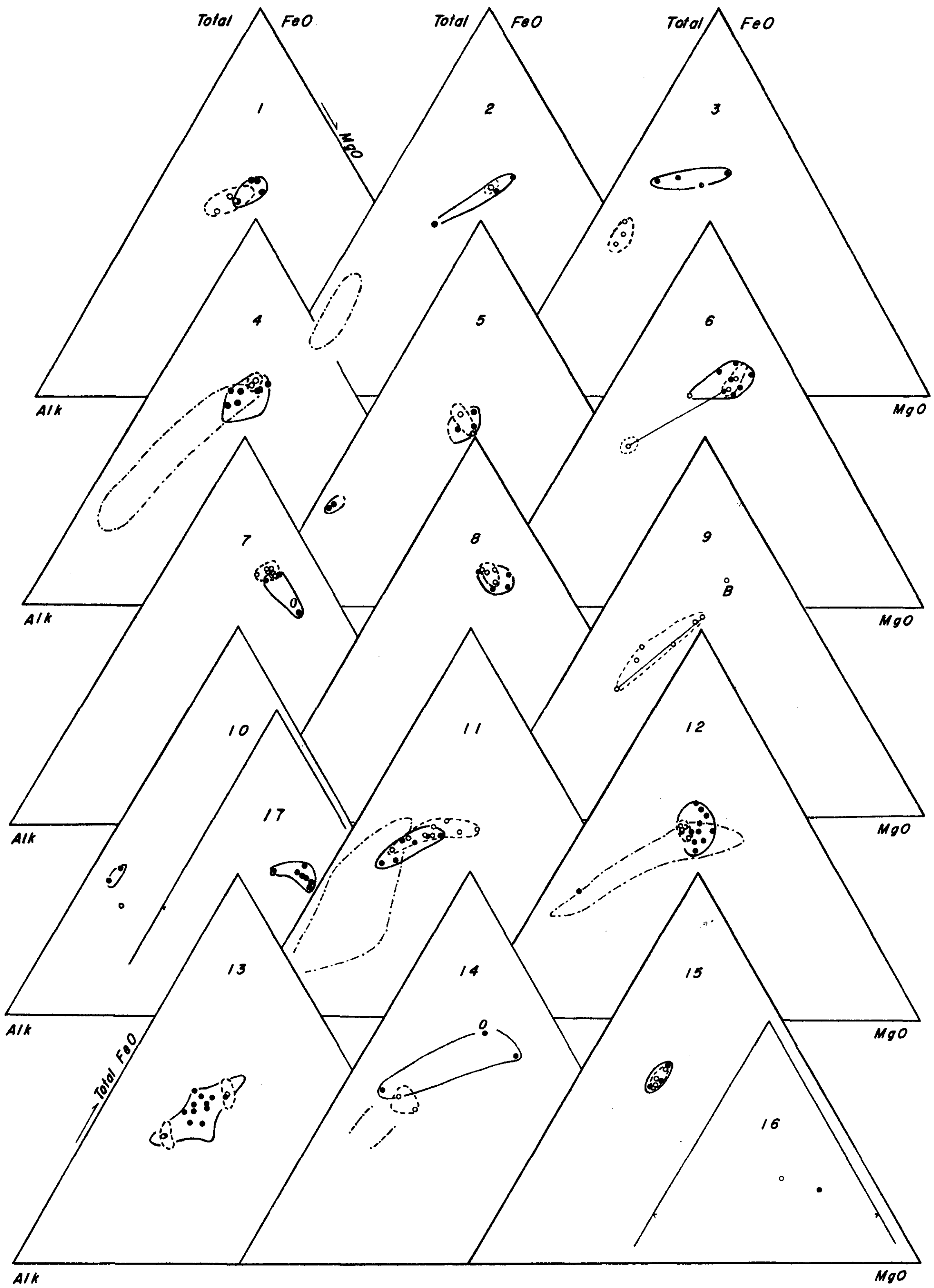

Fig. 9. Triangular diagram showing the ratio Total FeO : MgO : Alk of lavas of Japanese volcanoes, the lavas of historic times being enclosed by broken lines, and the lavas of prehistoric times enclosed by unbroken lines. Chain lines show the welded tuffs and lavas of the older volcanoes constructing the base of active volcanoes.

1 Komaga-dake, Hokkaido, 2 Tokati-dake, 3 Usu, 4 Tarumai, 5 Asama, 6 Huzi (Fuji) 7 Mihara-yama, Ôsima, 8 Miyake-zima, 9 Myozin-syo, 10 Iwo-zima, Volc. Is., 11 Sakura-zima (Sakura-jima), 12 Aso, 13 Unzen, 14 Iwo-zima, Satunan, 15 Suwanose, 16 Tori-siam, Izu, 17 Iwate.

Table 4. Relation between the lavas of historic times and those of prehistoric times in the ratio Total FeO : MgO : Alkalies

A	Lavas of historic times increase in Total FeO and/or Alkalies, compared with the lavas of prehistoric times.		
	Type *1*	Basic group	Mihara-yama, Ôsima; Miyake-zima (—Type 6); Tori-sima, Izu; Iwate
	Type *2*	Intermediate group	Komaga-dake, Hokkaido; Aso (excluding "Totinoki lava"); Iwo-zima (Satunan) (—Type 4)
	Type *3*	Acid group	Usu
B	Lavas of historic times decrease in Total FeO, compared with the lavas of prehistoric times which rich in Total FeO and Alkalies.		
	Type *4*		Iwo-zima (Volc. Ids.); Iwo-zima (Satunan) (—Type 2)
C	Lavas of historic times are separated into two groups, basic and acid		
	Type *5*		Myozin-syo; Huzi; Unzen
D	Almost unchanged through historic and prehistoric times		
	Type *6*		Suwanose-zima; Tokati-dake (—Type 7); Miyake-zima (—Type 1)
E	Reverse of A		
	Type *7*	Reverse of Type 2.	Sakura-zima; Tarumai; Asama
	Type *8*	Reverse of Type 1	
	Type *9*	Reverse of Type 3	
	Type *10*	Reverse of Type 4	

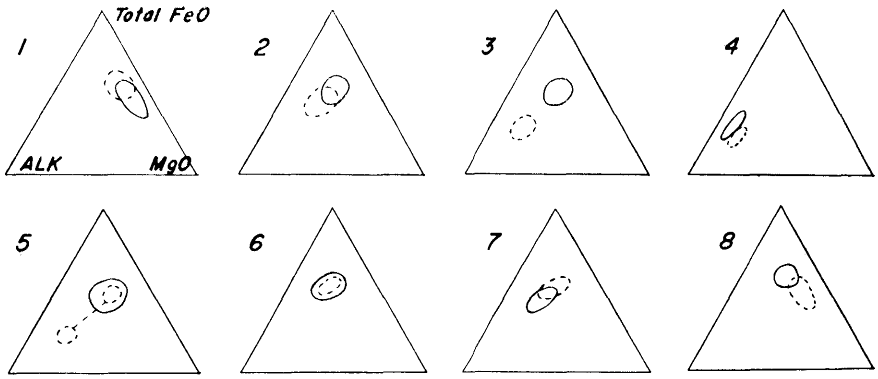

Fig. 10. Types of variation of lavas of historic (broken lines) and prehistoric (unbroken lines) times on the triangular Total FeO–MgO–Alkalies diagram. Nos. refer to Table 4.

More detailed descriptions on the relations between the eruption type and the lava sequence in the Total FeO–MgO–Alk diagram will be given in another paper.

VI. Appendix: Consideration from the petro-volcanological standpoint

Example

Sakura-zima

The Sakura-zima volcano (Lat. 31°35′N, Long. 130°39′E) is one of the most frequently erupted volcanoes in Japan. The eruptions of 1475–76, 1779, 1914 and 1946 flowed out lavas from the craters in the flank and foot of the volcano. The 1939 and 1956-present eruptions were also comparatively violent with emission of bombs. The acidity or 100 Alk/Total FeO+MgO+Alk of the products has decreased successively throughout historic times until 1939, and then began to increase through the present summit eruption, as shown in Figs. 11. The 1946 lava has the less contaminated character. Concerning the eruptions of historic times, it is noticed that (1) the centres of eruptions in the flank have moved upwards successively throughout historic times, (2) the time intervals between the distinctive eruptions have decreased successively throughout historic times and (3) the depression of the ground caused by the eruption occurred in the Aira caldera and in its surrounding area, the main centre of subsidence agreeing with the form of the Aira caldera and the Sakura-zima volcano being only a subordinate centre. Considering these facts just mentioned and the relationship between the capacity of magma chamber, the temperature decrease, the differentiation degree, the trend of fractionation of magma, the length of dormant period prior to eruption and the amount of lavas effused by the eruption, I assume (a) the existence of two magma chambers, one (1) of which is situated at a deep place (about 10 km) under the Aira caldera and larger than another one (2) which is situated at comparatively shallow place beneath the Sakura-zima volcano, and (b) the upwards moving of the chamber (2) through historic times. The capacity of the chamber (2) (about 1000 m in radius) has hardly varied through the historic times. It, however, may have decreased in capacity since the 1939 eruption. Such petrological extension of studies should be available for the consideration of possible eruption in the future also.

Table 5

Distinctive eruption (A.D.)	products (SiO_2)		Centre of eruption (Altitude in m.)	Time interval (years)	
766					
				705	
1471—1476	Lava	66.35 (av.)	180—Submarine		
				303	
1779	Lava	64.13 (av.)	700—Submarine		
				135	
1914	Lava	61.04→59.01	570—200		
				25	
1939	Bomb	57.11 (av.)	750		32
				7	
1946	Lava	61.25 (av.)	800		
				19	
1956—	Bomb	59.63	1060 (Summit)		

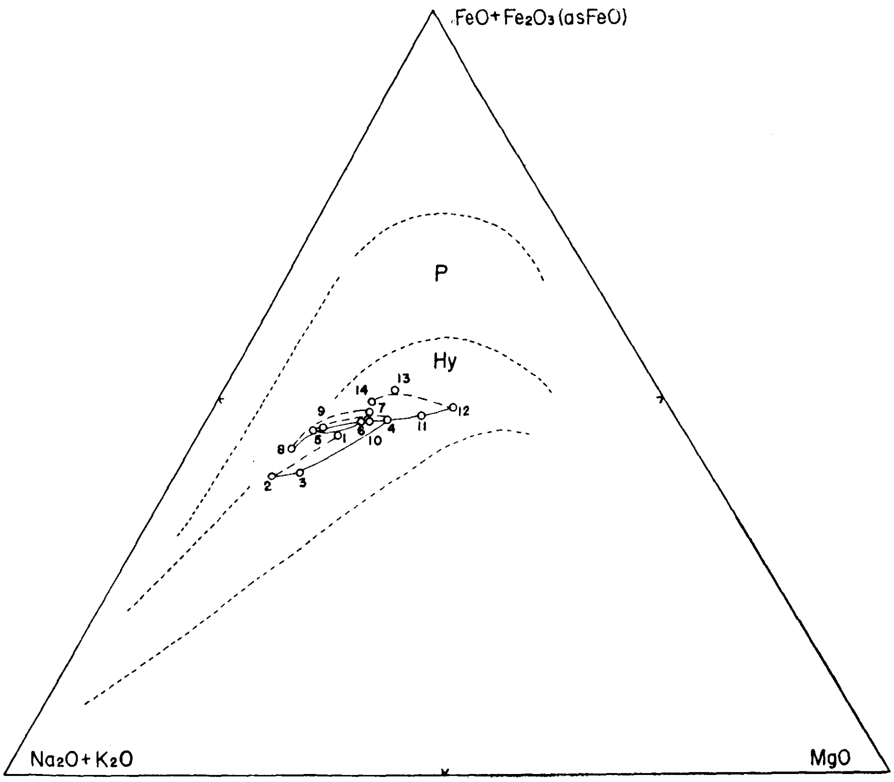

Fig. 11. Showing the fractionation trend and the sequence of effusions of Sakura-zima.

No.
1 Kita-dake lava (Augite-bearing hypersthene andesite)
2 Kita-dake Scoria (Do.)
3 Kita-dake, parasitic lava (Do.)
4 Minami-dake lava I [(Olivine- and) augite-bearing hypersthene andesite]
5 Minami-dake lava II and agglomerate containing Naka-dake agglomerate (Augite-hypersthene-andesite)
6 Lava of unknown period
7 Nabeyama (parasitic) ejecta (Two-pyroxene andesite)
8 Bunmei lava (1471, 1476) (Augite-hypersthene andesite)
9 An-ei lava (1779) [(Olivine-bearing) augite-hypersthene andesite]
10 Taisho lava I (1914) (Olivine-bearing augite-hypersthene andesite)
11 Taisho lava II (1914) (Do.)
12 Showa bomb I (1939) (Two pyroxene andesite)
13 Showa lava (1946) (Do.)
14 Showa bomb II (1956) (Do.)

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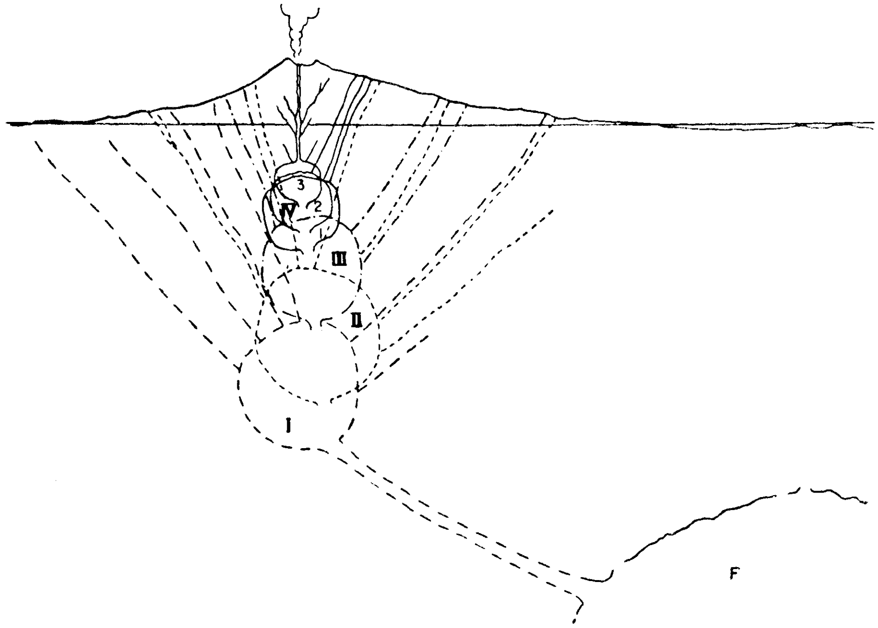

Fig. 12. Schematic sketch showing the upward moving of magna chamber 2.

I	Magma chamber 2	for the Bunmei eruption		(1946-76)
II	〃	for the An-ei eruption		(1779)
III	〃	for the Taisho eruption		(1914)
IV_1	〃	for tho Showa eruption		(1939-42)
V_2	〃		〃	(1946)
VI_3	〃		〃	(1955)

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Chemical analyses refer to Table 1.

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